GERMINATION, ESTABLISHMENT, GROWTH, UTILIZATION, AND CHEMICAL COMPOSITION OF INTRODUCED SHRUBS ON NORTH CENTRAL OKLAHOMA RANGELAND

By

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CHAPTER I

INTRODUCTION

This thesis was prepared using two manuscripts written in a format to facilitate immediate submission to scientific journals for publication. These manuscripts are presented as chapters in the thesis and each chapter is complete in itself. The manuscripts "Chemical scarification, moist prechilling, and thiourea effects on germination of 18 shrub species" (Chapter II) and "Establishment, growth, fall utilization and chemical composition of introduced shrubs on north central Oklahoma rangeland" (Chapter III) were written according to the style and format required for the JOURNAL OF RANGE MANAGEMENT. Appendices A - G complement Chapter II and H - K accompany Chapter III.

Approval for presenting the thesis in this manner is based upon the Graduate College's policy of accepting theses written in manuscript form. This approval is subject to the Graduate College's acceptance of the major professor's request for a waiver of the standard format.

CHAPTER II

CHEMICAL SCARIFICATION, MOIST PRECHILLING, AND THIOUREA EFFECTS ON GERMINATION OF 18 SHRUB SPECIES

Abstract

The major problem of increasing palatable perennial shrubs under range conditions is getting them established. Seed of many shrub species germinate poorly or are slow to germinate and grow. The objective of this study was to determine the effects of chemical scarification, moist prechilling, and thiourea on promoting seed germination in 18 different shrub species. Scarification involved 0, 3, 6, 9, and 12-hour soaking intervals in concentrated sulfuric acid, 10% hydrogen peroxide, and 5.25% sodium hypochlorite (clorox). Moist prechilling prior to germination was conducted on vermiculite moistened with distilled water or 0.2% KNO_3 for either 0, 2, 8, and 16-weeks or 0, 2, and 10-weeks at 2°C dark environment. Seeds treated with thiourea were soaked for 0, 20, 40, and 60-minutes in a 0.3% solution. Alternating temperatures of 12.5°C (night) and 20°C (day) for 16 and 8 hours respectively were used to germinate seeds. Seeds were considered germinated when cotyledons or hypocotyl emergence was evident. Hydrogen peroxide was more effective in promoting seed germination than either clorox or sulfuric acid. However, neither clorox, hydrogen peroxide, nor sulfuric acid at the concentrations and soaking durations

studied were effective in promoting maximum germination. Regardless of moistening agent, maximum germination of most species was attained following moist prechill and response appeared directly related to prechill duration. Prechilling seeds for 0 and 2-weeks with 0.2% KNO_3 solution usually retarded germination. Whereas, prechilling seeds for 8-weeks or more with KNO_3 usually promoted germination. Thiourea concentration was too low or soaking durations too short to effectively promote germination.

Introduction

The importance of seasonal availability of palatable range shrubs and their adaptation and establishment on selected range sites has received little attention in the Southern Great Plains. This area of range improvement is recognized in the western range states (Cable 1972, Stevens et al. 1977) but direct seeding of desirable native shrubs has met with limited success. Poor stands are often attributed to poor seed germination. Seeds which do not germinate under favorable conditions, but may be induced to germinate are considered dormant (Mayer and Poljakoff-Mayber 1975). Dormancy is usually associated with temporary suspension of plant growth or lack of germination in seeds. Immature embyros, impermeability of seed coat to water or gasses, mechanical causes, special light, and temperature requirements, or the presence of germination inhibitors are factors which may cause seed dormancy (Mayer and Poljakoff-Mayber 1975). Quiescence is the failure of seeds to germinate under unfavorable environmental conditions (Amen 1963). After-ripening is referred to as the time or resting-stage required between seed maturity and the time seeds will germinate. After-ripening may be defined as any changes occurring in seeds during storage which results in improved germination (Mayer and Poljakoff-Mayber 1975).

Chemical and mechanical scarification, stratification, subjecting seeds to temperature extremes, soaking seeds in various concentrations of thiourea solutions, gibberellic acid, and combinations of one or more treatments have all been used to break seed dormancy (Everett and Meeuwing 1975; Liacos and Nord 1961; McConnell 1960; Pearson 1957; Walters 1970; McHenry and Jensen 1967, Carlson 1974).

A hard seed-coat may be impermeable to water, gasses, or may constrain the embyro. Scarification treatments are used to erode the seed-coat to improve permeability (Amen 1963). Stratification is believed to limit the effects of inhibitors while promoting growth stimulators such as gibberellic acid. Dilute solutions of potassium nitrate and gibberellic acid are growth stimulators and different concentrations have been used to promote germination of different species (Mayer and Poljakoff-Mayber 1975). Mirov (1936) observed that stratification treatments increased germination of seeds from plants growing at elevations greater than 1200 m. While scarification treatments in some instances increased germination for species growing at elevations less than 300 m. Considerable difficulty has been encountered by others in establishing palatable shrub species by direct seeding. With this in mind, the objective of our study was to determine the effects of different pre-germination techniques on seed germination of 18 shrub species.

Methods

Species selected for evaluation and study were bitterbrush (Purshia tridentata), fourwing saltbush (Atriplex canescens), inland Jersey tea (Ceanothus ovathus), serviceberry (Amelanchier alnifolia), big sagebrush (Artemisia tridentata), shadscale (Atriplex confertifolia), snowbrush (Ceanothus velutinus), winterfat (Ceratoides lanata), curlleaf mountainmahogany (Cercocarpus ledifolius), cliffrose (Cowania mexicana var. stansburiana), Morman tea (Ephedra viridus), Apache-plume (Fallugia paradoxa), prostrate kochia (Kochia prostrata), shrubby cinquefoil (Potentilla fruticosa), golden currant (Ribes aureum), woods rose (Rosa woodsii), wedgeleaf ceanothus (Ceanothus cuneatus), and chamise (Adenostoma fasciculatum). Scientific nomenclature according to Soil Conservation Service 1971 and USDA Forest Service 1977.

Criteria for selection of these species was the availability of seed and reported utilization and winter nutritive value for livestock and big-game. Seeds were obtained from Soil Conservation Plant Materials Centers and from commerical seed sources. Heavy well-filled seed was separated from the light, empty, or immature seed with the aid of a South Dakota seed blower.[1/] All seeds utilized in germination studies were counted by hand and considered uniformily well-filled complete seed units. Processing, if any, and storage conditions of seed prior to initiation of study is not known.

Pre-germination treatments involving chemical scarification, moist prechilling, and soaking in thiourea were replicated 3 times with 25 seeds in each replication. Germination studies were arranged in a

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randomized complete block design and conducted in a Stultz Da-lite germinator set for alternating temperatures of 12.5°C (night) and 20°C (day) for 16 and 8 hours, respectively. Containers used for all germination studies were clear plastic germination boxes 7x7x3 cm containing 70 ml of vermiculite and covered with another 30 ml. The uniformity of substrate moisture added to the vermiculite in each box was determined by volume. Each scarification, moist prechill, and thiourea soaking treatment involving different treatment durations were so arranged as to be concluded simultaneously (i.e. 16-week prechill treatment ended at the same time as the 2-week treatment). Germination counts were made at 7-day intervals for a period of 4 weeks. Seeds were considered germinated when A) the cotyledons or B) hypocotyl emergence was evident.

Chemical Scarification

Concentrated sulfuric acid (H_2SO_4) , 10% hydrogen peroxide (H_2O_2) , and 5.25% sodium hypochlorite (Na^+OCl^-) were used in chemical scarification studies. Scarification treatments involved soaking the seeds in each chemical for 0, 3, 6, 9, and 12-hour durations. The control consisted of no pre-treatment of the seed prior to germination. Seeds were placed in each chemical scarification solution at various time intervals so that all the seeds of all treatments could be removed at the same time, thoroughly washed under running tap-water, and placed in germination boxes prior to entry into the

the germination environment.

Due to the difficulty of obtaining sufficient seed of all species requested, only seeds of bitterbrush, fourwing saltbush, and Jersey tea were used in the scarification and prechill experiments.

Prechill Treatments

Seed treatments in these studies consisted of placing the seeds in germination boxes filled with vermiculite, moistened with the appropriate solution of either 0.2% KNO_3 or distilled water, and prechilling in the dark at 2°C. Bitterbrush, fourwing saltbush, and Jersey tea seeds were subjected to prechill duration of 0, 2, 8, and 16 weeks. Due to insufficient seed, the remaining species were prechilled prior to germination for 0, 2, and 10 weeks. The lid of each box was taped to prevent evaporation loss during prechill.

Thiourea Treatments

Thiourea treatments consisted of soaking seeds in a 0.3% solution of thiourea for 0, 20, 40, and 60 minutes. The control consisted of no pre-soaking of the seed. Following treatment, seeds were thoroughly washed under running tap-water, transferred to germination boxes, and placed in the germinator.

The data were analyzed on an IBM 370/158 computer using the ANOVA procedure of the Statistical Analysis System (Barr and Goodnight 1972).

Results and Discussion

Scarification Studies

The effects of chemical scarification treatments on seed germination were variable depending upon the chemical and soaking duration. Scarification with hydrogen peroxide had the highest average seed germination while scarification with sulfuric acid resulted in the lowest (Fig. 1). With the exception of bitterbrush seeds scarified for 6 hours in hydrogen peroxide, scarification reduced germination below that of the control in all species. Treated bitterbrush and Jersey tea seeds failed to germinate after soaking in concentrated sulfuric acid. Germination of fourwing saltbush and Jersey tea seeds following scarification in all chemicals was far below that of the unscarified controls.

Clorox and concentrated H_2SO_4 appear to be severe chemicals for seed scarification of all three of these shrub species. Soaking the seeds in less concentrated solutions, for shorter durations, with all three chemicals studied may have altered the results of this study. Further investigations along these lines are needed.

Moist Prechill Treatment Effects, Distilled Water and KNO_3

Compared to distilled water as a substrate moistening agent during prechill, a 0.2% KNO_3 solution increased, although not significant, germination of bitterbrush and Jersey tea. Fourwing saltbush seed germination was not affected by prechill moistening agent. Regardless of substrate moisture, prechill effects on seed germination of all three species were highly significant (Figure 2). A direct

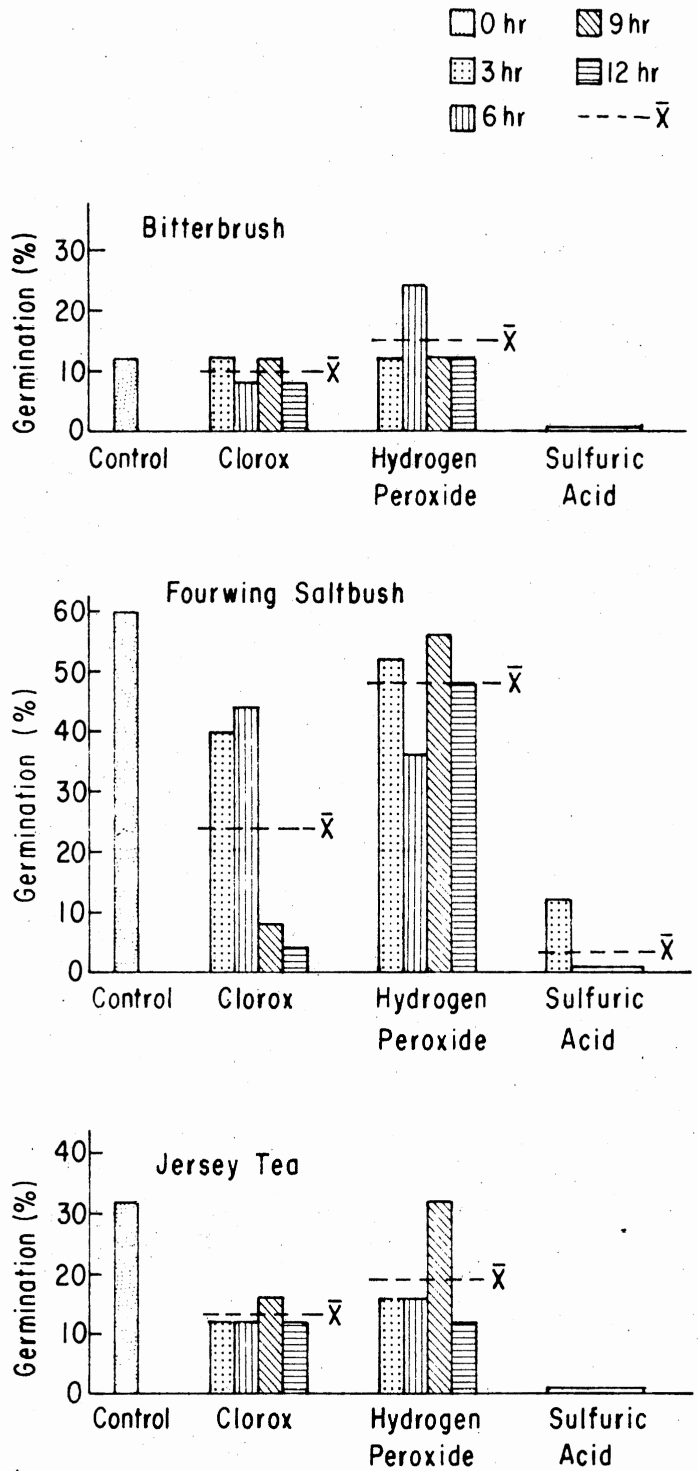

Fig. 1. Mean germination (%) effects of 3 chemicals and 4 soaking time intervals on seeds of 3 browse species. Time X Treatment LSD $_{0.05}$; bitterbrush 5.8; fourwing saltbush 8.0; Jersey tea 5.5.

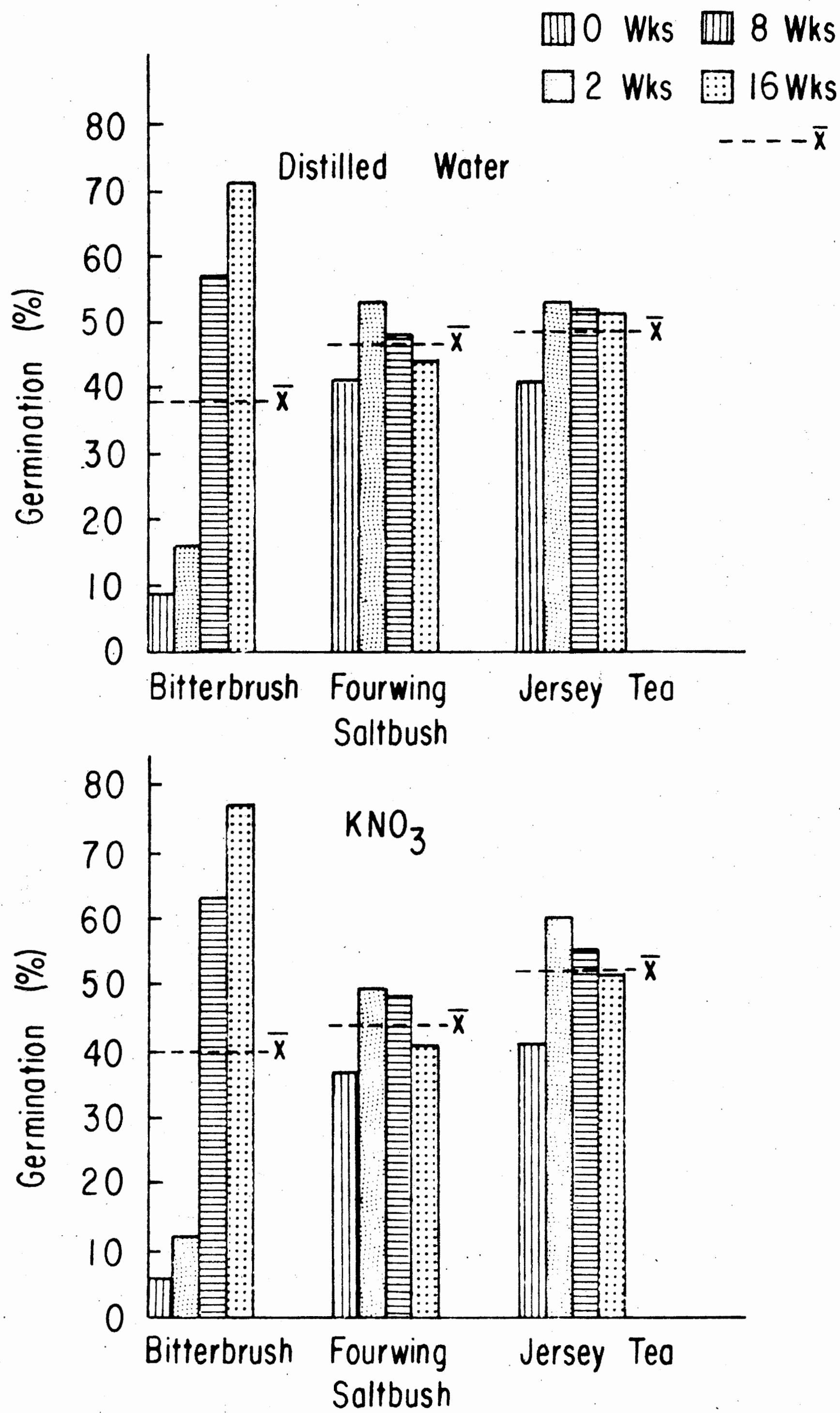

Fig. 2. Mean germination (%) effects of 2 moistening agents on seeds of 3 browse species prechilled for 0, 2, 8, and 16 weeks. Time X Treatment LSD $_{0.05}$; bitterbrush 4.2; fourwing saltbush 5.7; Jersey tea 4.4.

relationship existed between the mean germination of bitterbrush seeds and length of prechill duration with both moistening agents. Maximum germination occurred following a 16-week prechill treatment. Whereas, germination of fourwing saltbush and Jersey tea seeds decreased when subjected to moist prechill durations beyond 2 weeks. Fourwing saltbush and bitterbrush seeds began to germinate while in the prechill environment (2°C) in the 8 and 16-week treatment duration.

Germination averages of Morman tea and shrubby cinquefoil seeds (Figure 3a) were greater when prechilled on substrate moistened with distilled water. Maximum germination of winterfat occurred when seeds received no prechill treatment and were germinated on vermiculite moistened with distilled water. There was an indirect relationship between winterfat seed germination and length of prechill treatments using distilled water as substrate moistening agent. Big sagebrush, curlleaf mountain-mahogany, cliffrose, and golden currant had significantly greater germination averages when prechilled on substrate moistened with KNO_3 (Figure 3b). Although not statistically significant, germination of shadscale seeds was greater when prechilled on substrate moistened with 0.2% KNO_3 rather than distilled water. Germination was sufficiently high to suggest that longer prechill durations may induce a greater number of seeds to germinate. Neither moistening agent nor prechill duration had much effect on germination of Apache-plume.

In general, the use of 0.2% KNO_3 solution as substrate moisture without prechill had no beneficial effect on seed germination over distilled water. However, in combination with prechill the use of KNO_3 on seed germination had 1) a beneficial effect on seeds of big

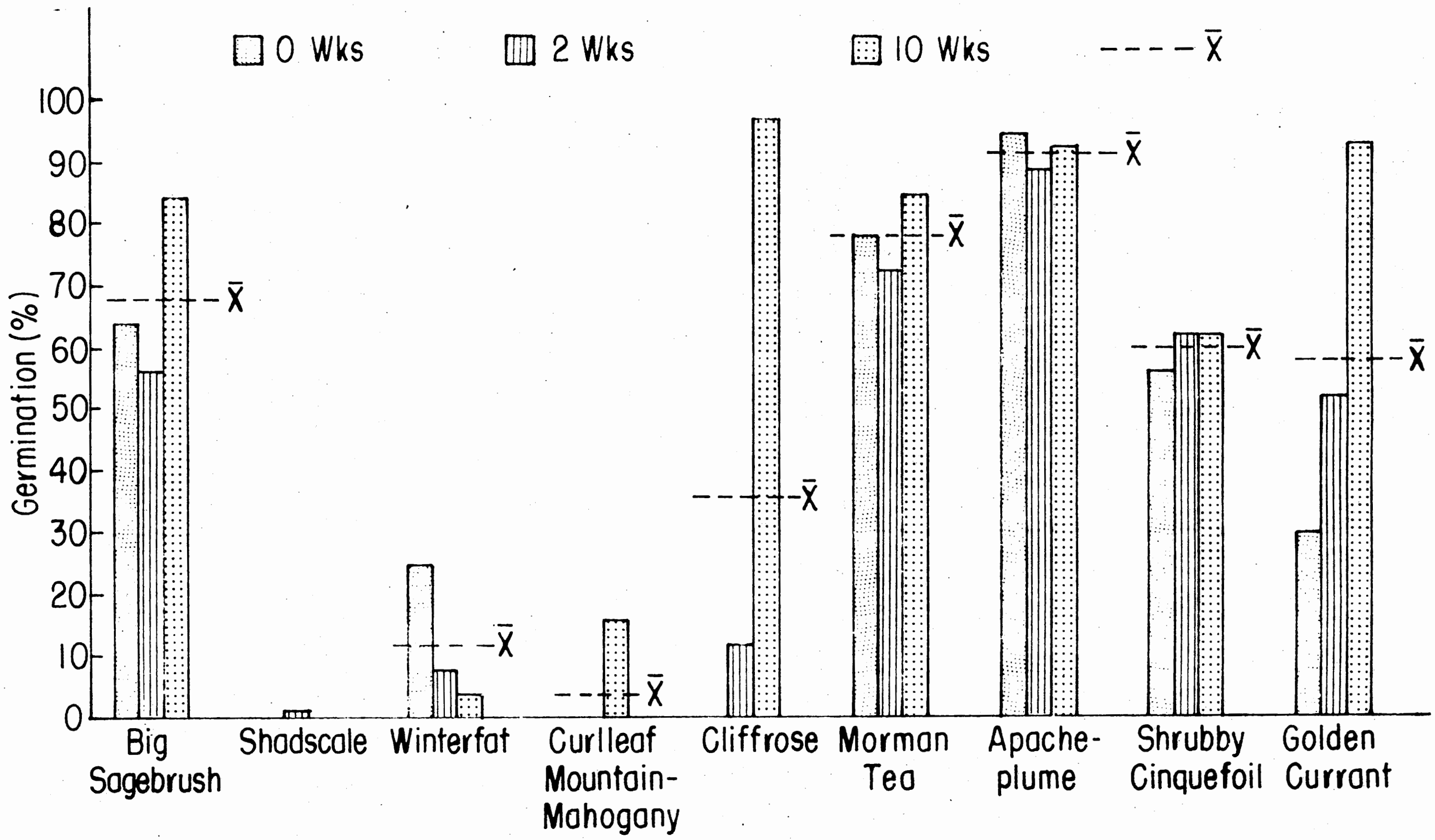

Fig. 3a. Mean germination (%) effects of distilled water as a moistening agent on seeds of 9 browse species prechilled for 0, 2, and 10 weeks Time X Treatment LSD $_{0.05}$; big sagebrush 30.0; shadscale 12.0; winterfat 7.6; curlleaf mountain-mahogany 9.5; cliffrose 7.3; Morman tea 14.6; Apache-plume 17.4; shrubby cinquefoil 17.3; golden currant 18.2.

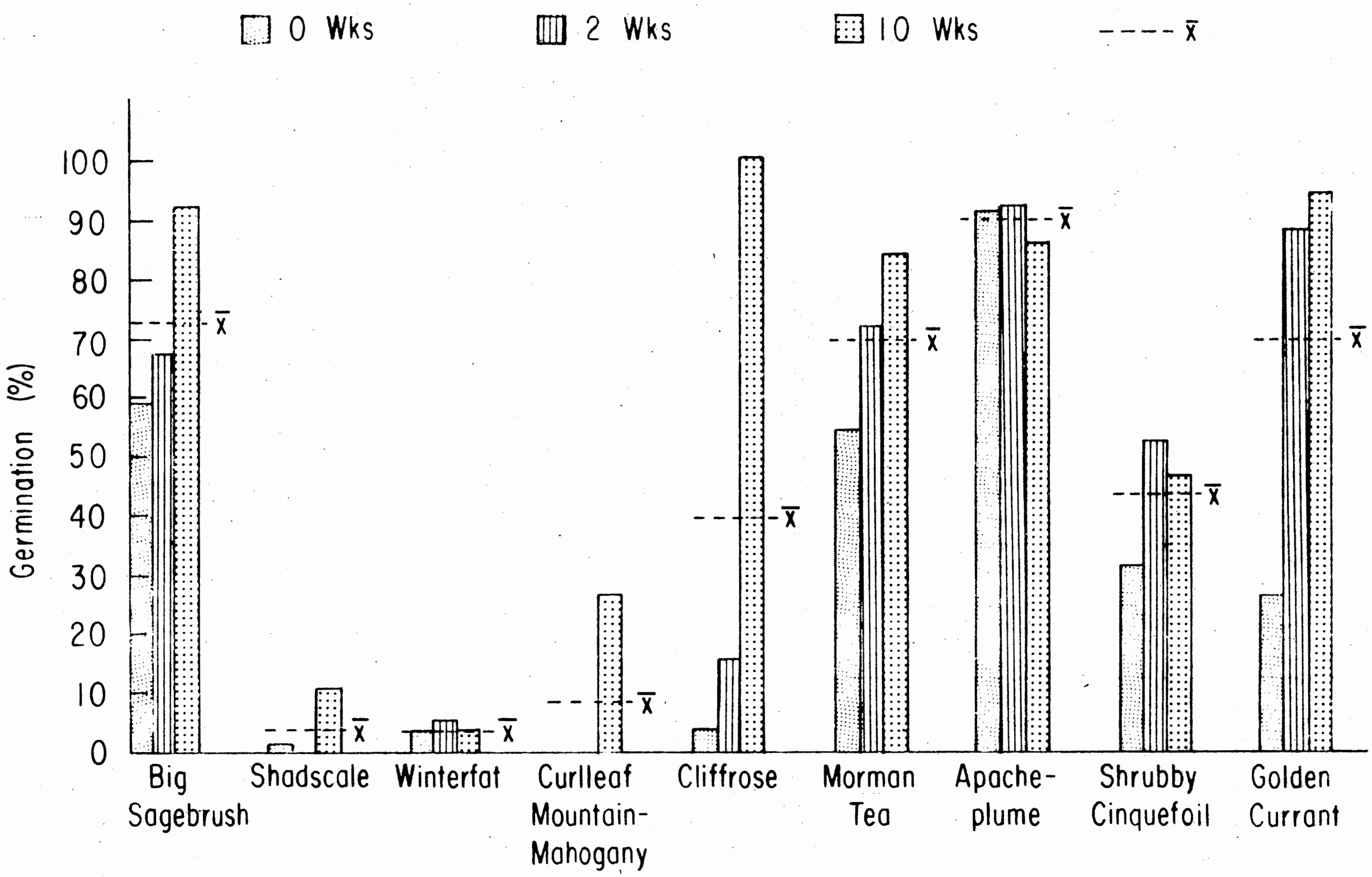

Fig. 3b. Mean germination (%) effects of 0.2% KNO_3 solution as a moistening agent on seeds of 9 browse species prechilled for 0, 2, and 10 weeks. Time X Treatment LSD $_{0.05}$; big sagebrush 30.0; shadscale 12.0; winterfat 7.6; curlleaf mountain-mahogany 9.5; cliffrose 7.3; Morman tea 14.6; Apache-plume 17.4; shrubby cinquefoil 17.3; golden currant 18.2.

sagebrush, shadscale, curlleaf mountain-mahogany, cliffrose, and golden currant; 2) little or no effect on others such as Apache-plume; and 3) a threshold antagonism to winterfat and shrubby cinquefoil. Regardless of prechill duration, the 0.2% KNO_3 substrate moistening agent had a tendency to delay seed germination during the first 7-14 days incubation. However, there was a trend for this delayed effect to be reduced as prechill duration increased.

Potassium nitrate appeared to stimulate early germination of golden currant. With the exceptions of winterfat, Apache-plume and shrubby cinquefoil, seed germination of all species studied responded to moist prechill. Apache-plume seeds germinated readily, 90%, regardless of treatment combination.

A direct relationship was observed, in most species, to exist between maximum germination and prechill treatment duration. Maximum germination of big sagebrush, shadscale, curlleaf mountain-mahogany, cliffrose, Morman tea, and golden currant was attained after a 10-week prechill duration. The need for moist prechill durations longer than 10 weeks were evident to attain maximum seed germination of shadscale and curlleaf mountain-mahogany.

Regardless of substrate moitening agent used during prechill and duration of prechill, serviceberry, snowbrush, prostrate kochia, woods rose, chamise, and wedgeleaf ceanothus failed to germinate or germinated less than 5%. Data suggests that germination of snowbrush and wedgeleaf ceanothus seeds might have been greater if prechill durations with either moistening agent had been longer. Apparently treatments other than moist prechilling is required to germinate seeds of serviceberry, prostrate kochia, and woods rose.

Thiourea Treatment Effects

Golden currant was the only species in which thiourea was found to significantly promote germination. Maximum germination of golden currant seeds occurred after seeds were soaked for 40 minutes in a 0.3% thiourea solution prior to germination.

Bitterbrush, Jersey tea, winterfat, prostrate kochia, and shrubby cinquefoil seed germination results were similar to that observed by Pearson (1957). He observed an inverse relationship between the concentration of thiourea and length of soaking time required for increased bitterbrush seed germination.

Interactions between light, temperatures, and thiourea concentration affect seed germination (Mayer and Poljakoff-Mayber 1975). It is apparent the concentration of the thiourea solution used in this study was too low and soaking time periods too short to effectively promote germination of all study species except golden currant.

Parameters or Test Variables That May Have Influenced Germination Results

Condensation and dripping caused flooding in the germination boxes once lids were removed. Germination box position and tray level in the germinator had little effect upon flooding. After each seedling count, excess water was drained from each box. Effect of flooding upon germination values is not known. Water from boxes containing bitterbrush seeds was reddish brown in color. It was observed that germination usually began in this species after an unknown amount of this substance was leached from the seed. Since germination followed leaching it is suspected that this substance contained a germination inhibitor.

In conclusion, many of the shrub species studied are slow to germinate and grow, an understanding of the germination requirements should be advantageous in establishing them under range conditions. It appears highly unlikely that planting seed of bitterbrush, shadscale, big sagebrush, cliffrose, curlleaf mountainmahogany, and golden currant would result in suitable stands if planted in the spring. The prechill requirements for maximum germination suggest that fall planting dates are required. Other species such as Apache-plume, shrubby cinquefoil, and Morman tea would appear to be equally suited to fall and spring establishment dates. Species which require no prechill or a short prechill duration such as winterfat, fourwing saltbush, and Jersey tea could be planted in the spring. However, spring seedlings often have a high mortality due to drought conditions occurring before plants can establish a supportive root system.

Spring transplanting of containerized shrub species grown in the greenhouse showed promise as a way of establishing these species on problem areas. Transplants avoid high seedling mortality due to poor root establishment and in general gives the species a head start on survival. The use of containerized transplants may be of value in restoring depleted livestock and big-game winter ranges, reclaim strip-mined lands, revegetate road cuts, or used in areas in which wind and water erosion is a problem. Containerized plants could in part be an effective method of revegetating lands in which natural revegetation by parent stock or direct seeding is too slow due to environmental conditions.

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CHAPTER III

ESTABLISHMENT, GROWTH, FALL UTILIZATION, AND CHEMICAL COMPOSITION OF INTRODUCTED SHRUBS ON NORTH CENTRAL OKLAHOMA RANGELAND

Abstract

On April 1, 1977, 14 species of containerized shrubs were transplanted onto north central Oklahoma rangeland to determine growth, survival, fall utilization, chemical composition, and digestibility of introduced shrubs. One-half of the available plants of each species were transplanted onto Lucien loam (Udic Ustochrepts) and one-half onto Grainola silt loam (Vertic Haplustalfs) soils. Plants were enclosed in mammal graze-proof wire cages throughout the summer. Mid-range growth and number of live plants were determined for each pot on April 1, September 1, and November 20. On September 1, cages were removed from around one-half of the pots of each species on each soil type to allow grazing. Mean summer plant growth was determined as the difference between September and April mean mid-range growth for each species. Fall utilization was determined as the difference between September and November mean mid-range growth. Survival was considered the difference between the number of April and November live plants. Growth and survival were greater on the deeper Grainola soil, while utilization was greater on the Lucien soil. Nitrogen, phosphorus, potassium, and calcium contents and *In Vivo* dry matter

digestibility were much greater in fall caged shrubs than in native herbaceous samples collected from the same area at the same time.

Introduction

With a decreasing acerage of Oklahoma rangeland and an increasing demand for meat, there is an increased production pressure on our rangelands. To increase meat production on our rangelands, not only must the forage quality and carrying capacity be increased, but the period of adequate forage quality needs to be extended.

No forage class (i.e., grass, forbs, shrubs) maintains a high nutritional level throughout the year. Most forage plants are high in nutritive value during early growth but their forage value declines rapidly as they mature. However, some classes mature slowly and maintain higher nutrient levels over an extended period (Cook 1972).

Browse plants have a relatively high level of crude protein throughout the year. However, crude protein, phosphorus, and carotene levels decrease with plant maturity while calcium and fiber components increase. In general, shrubs contain higher percentages of crude protein during fall and winter, but less during spring and summer than grasses or forbs. The levels of these components in forbs are usually intermediate between grasses and shrubs (Cook and Harris 1968, Cook 1972, Oelberg 1956).

Maturation accompanied by a change in the stem-to-leaf ratio is largely responsible for seasonal changes in chemical composition in all forage plants (Cook et al. 1956). Seasonal changes in chemical composition are less dramatic in shrubs, however, than in grasses or forbs. Shrubs maintain higher nutritional levels during dormancy due to the translocation of nutrients from the leaves to the stems before leaf abscission (Kramer and Kozlowski 1960). Stems then provide browse throughout the fall and winter.

Establishment of adapted browse plants in tallgrass prairies would increase rangeland carrying capacity as well as plant species and diet diversity. Rangelands with more diverse vegetation are often more suitable for common use by sheep, cattle, and goats than for single use by only one kind of animal (Cook 1954, Merrill and Young 1954, Merrill et al. 1966). In Texas, proper stocking with two or more kinds of livestock maintained or improved range condition (Merrill et al. 1966).

Season of use and nutrient content of forage often determines degree of utilization and plant species eaten (Wallace et al. 1972). As seasons change and the number of plant species available for utilization decrease, competition between kinds and classes of livestock increases (Cook et al. 1967, Rosiere et al. 1975). Even as nutritive value and digestibility of plants decrease, selective grazing of plant species and plant parts enable animals to maintain a higher quality diet than when grazing vegetation with low species diversity (Laycock and Price 1970). Therefore, the objectives of this study were to introduce containerized shrub seedlings onto two tallgrass prairie range sites and determine 1) plant growth, 2) plant utilization, 3) species survival, and 4) plant chemical composition after one full growing season.

Study Area

The study area is on the Stillwater Creek Experimental Range located in north central Oklahoma at coordinates 37°7' latitude, 97°17' longitude, and 22 km west of Stillwater, Oklahoma. The elevation of the area ranges from 287 m along Stillwater Creek to 297 m at the north boundary (George 1974).

The area has a continental climate with an annual mean minimum temperature of 9°C and a mean maximum temperature of 22°C. The average absolute minimum is -14°C from November through March with the absolute maximum temperature exceeding 40°C June through August. The annual precipitation averages 820 ± 250 mm. The average precipitation distribution during the 192-day growing season is 23% (April - May), 34% (June - August), 19% (September - October), and 23% (November - March) (Meyers 1976). The establishment sites were located in good condition tallgrass prairie vegetation previously used as a hay meadow or moderately grazed during the summer by steers.

Both soil types in the study area are Shallow Prairie range sites. The common soil parent materials are sandstone and shale. These are common parent materials often occurring throughout the Oklahoma Reddish Prairies (Gray and Roozitalab 1976). Grainola and Lucien soil series comprise the study area. Grainola silt loam is a fine, mixed, thermic Vertic Haplustaf. It is a deep, well drained, slowly premeable soil with a moderate water holding capacity. Lucien silt loam in the study area is a loamy, mixed, thermic, shallow Udic Ustochrept, although Lucien soils are normally classified Udic Haplustolls. It is a shallow, well drained, moderately rapid permeable soil with a low water holding capacity (Gray and Nance 1978).

The vegetation on the Grainola soil is indicative of a deeper soil with a moderate water holding capacity. The vegetation is dominated by big bluestem (Andropogon gerardii), little bluestem (Schizachrium scoparium), and Indiangrass (Sorghastrum nutans). The vegetation on the Lucien soil is typical for shallow, xeric soil. Dominant species include blue grama (Bouteloua gracilis), hairy grama (Bouteloua hirsuta), side-oats grama (Bouteloua curtipendula), silver bluestem (Bothriochloa saccharoides), and Japanese brome (Bromus japonicus). Scientific nomenclature of species is according to Gould (1968). A view of the study areas is shown in Figure 1.

Fig. 1. View of the study area.

Methods

On April 1, containerized seedlings of bitterbrush (Purshia tridentata), fourwing saltbush (Atriplex canescens), Jersey tea (Ceanothus ovatus), big sagebrush (Artemisia tridentata), shadscale (Atriplex confertifolia), snowbrush (Ceanothus velutinus), winterfat (Ceratoides lanata), curlleaf mountain-mahogany (Cercocarpus ledifolius), cliffrose (Cowania mexicana var. stansburiana), Morman tea (Ephedra viridus), Apache-plume (Fallugia paradoxa), shrubby cinquefoil (Potentilla fruticosa), golden currant (Ribes aureun), and wedgeleaf ceanothus (Ceanothus cuneatus) were removed from the greenhouse and transplanted in the study area. Fringed sagebrush (Artemisia frigida) and true mountain-mahogany (Cercocarpus montanus) plants were transplanted from southeastern Colorado onto the study area at this time. One-half of the number of available plants of each species were planted on each of 2 soil types in the study area. The bottom of each transplanted pot was removed and additional cuts were made in the side to facilitate root growth. Mid-range growth was determined by measuring the height of the tallest and shortest plant in each pot. Plants were enclosed with mammal graze-proof wire cages (Fig. 2) and watered periodically throughout the summer to prevent grazing and minimize soil water stress.

On September 1 mid-range plant growth was determined for each species and each pot. The number of live plants in each pot was recorded. Summer plant growth was determined by subtracting April mid-range growth from September mid-range growth. Cages placed over one-half of the pots of each species on each soil type were removed at

Fig. 2. Mammal graze-proof wire cage.

this time to allow grazing by cattle and wildlife. Pots were also removed from around plants to reduce livestock curiosity.

On November 20, after freezing temperatures had stopped plant growth, mid-range growth and number of live plants were determined for both caged and uncaged (grazed) plants. Fall growth of ungrazed plants was determined by subtracting September mid-range caged plant growth from November mid-range caged plant growth. Utilization was determined by subtracting November mid-range grazed plant growth from September mid-range grazed plant growth. Species survival was determined by subtracting the number of live plants in November from the number of live plants in April. Current growth was collected from plants caged throughout the fall for chemical analysis and nylon bag dry matter digestibility (NBDMD).

Plant samples were dried at room temperature (25°C) for 10 days and ground in a Wiley mill with a 2-mm mesh screen for chemical analysis. Samples were analyzed for kjeldahl nitrogen, phosphorus, potassium, and calcium (OSU Soil and Water Testing Laboratory, Unpublished procedures). Dry matter content (%) was determined by heating duplicate 2-gram samples for 24 hours at 100°C. Three rumen-fistulated steers were used for NBDMD determinations (Johnson 1969). A 3-gram aliquot of each sample was placed in each steer for 48 hours. Samples were removed from steers, washed, dried at 60°C for 48 hours and reweighed to determine NBDMD.

Data were analyzed using an IBM 370/158 computer and the ANOVA procedure of the Statistical Analysis System (Barr and Goodnight 1972). Statistical comparisons for plant growth, utilization, and species survival were made by species and between soil types. Soil types were not replicated. Statistical comparisons for plant chemical composition and NBDMD were made by species. All differences discussed were significant at the 5% level of probability unless otherwise specified.

Results and Discussion

Weather

Total precipitation during the growing season was near normal for the area. However, precipitation distribution differed from the normal monthly rainfall averages. Above normal precipitation occurred during May, July, and August. May precipitation was more than 100% greater than normal while July and August averaged 35% above normal. June rainfall was only 18% of the normal average. Precipitation in September and November was near normal while rainfall in October was 50% below normal. Throughout the growing season maximum temperatures averaged 1.6°C greater than normal while mean temperatures averaged 2.4°C above normal. Wind movement averaged 2573 km/mo throughout the growing season (Table 1). May rainfall enabled plants to establish root systems before the onset of hot and dry weather.

Species Growth by Soil Type

Summer plant growth varied among species and between soil types (Fig. 3). Growth ranged from 1 to 30 cm depending upon the species. Big sagebrush, fourwing saltbush, and Apache-plume growth was not affected by soil type. Apparently these species are equally adaptable to both soils. However, Apache-plume flowered on the Grainola soil, but not on the Lucien soil. The greater water holding capacity of the deeper and more mesic Grainola soil might have been an influential factor in Apache-plume flowering.

Curlleaf mountain-mahogany, Morman tea, and golden currant plants failed to grow well on either soil type. The growing points on twigs of these species died during the summer. September mid-range plant growth was less than initial April plant height for these species. Morman tea twig tips dried and became brittle in late July. Leaves of golden currant turned brown and fell from plants on both soil types by early July. However, after a rain in mid August and several days of cooler temperatures, some golden currant plants on the Lucien soil began to produce new leaves. New leaves began to appear on golden currant plants on the Grainola soil immediately after September plant

Table 1. Monthly precipitation (mm), temperature (°C), and wind (km/mo) values during the 1977 growing season.

	Climatic Factor			
	Precipitation (mm)	Temperature (°C)		Wind (Km/month)
		Mean	Absolute Maximum	
April	68	14	30	2674
May	237	20	32	2801
June	20	24	37	2565
July	115	29	41	2646
August	117	27	38	2572
September	67	24	36	2459
October	31	17	36	2141
November[1/]	48	11	27	2732

[1/] Values are for the first 20 days of November

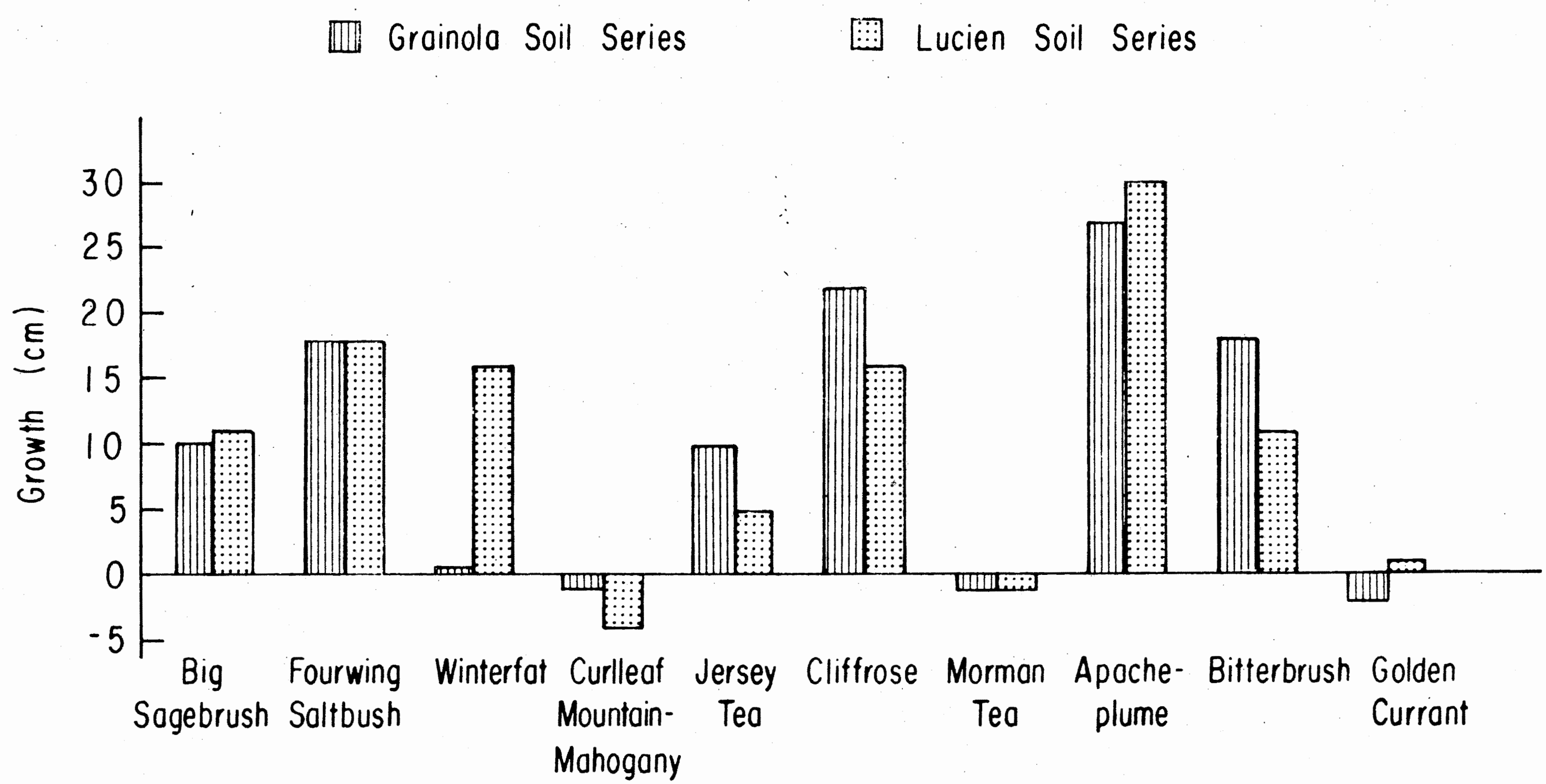


Fig. 3. Mid-range summer growth (cm) averages of 10 introduced shrub species on 2 soil types. Negative growth indicates plants in which terminal portion of stems died during the summer.

measurements. The more readily available soil water in the Lucien soil was probably responsible for the earlier leaf production of golden currant.

Fringed sagebrush and true mountain-mahogany were transplanted from southeastern Colorado onto the study area at the same time the other species were transplanted from the greenhouse. April mid-range growth was not determined so summer growth was not known for these species. Fringed sagebrush plants on the Lucien soil produced seed whereas plants growing on the Grainola soil did not. Seed production may have been induced by the more xeric Lucien soil. True mountain-mahogany plants were pruned before transplanting. Plants on both soil types produced very little woody stem growth but an abundance of leaves where stems were cut.

Winterfat, Jersey tea, cliffrose, and bitterbrush growth was affected by soil type. Winterfat growth was 15 cm greater for plants growing on the more xeric, Lucien soil. Winterfat plants never attained an erect growth form or developed strong woody stems which are characteristic of this species in native habitat.

Jersey tea, cliffrose, and bitterbrush plants growing on the Grainola soil exhibited increased growth of 100%, 37%, and 63%, respectively, greater than plants of these species growing on the Lucien soil. The increased plant growth was probably due to the greater water holding capacity of the Grainola soil. The Lucien soil is a shallower soil with more rapid permeability and a lower water holding capacity than that of the Grainola soil. Differences in growth of winterfat, Jersey tea, cliffrose, and bitterbrush due to soil type indicate these species have particular requirements which influence adaptability. Fall growth was negliglible for all species studied.

Species Utilization by Soil Type

Utilization differences were greater among species than between soil types (Fig. 4). Utilization ranged from 0 to 23 cm of vegetative growth depending upon the species.

Browsing of true mountain-mahogany, Jersey tea, and Apache-plume was greater on the shallower Lucien soil. Cook (1959) found that plants growing on shallower soils were more leafy and produced smaller stems than the same species growing on deeper soils. Stem:leaf ratios were not determined in this study. Utilization was not correlated with plant height growth. Apache-plume plants in September and the same plants in November after browsing are shown in Figure 5.

Utilization of fringed sagebrush, big sagebrush, fourwing saltbush, Morman tea, and golden currant was not affected by soil type. Apparently soil type did not influence plant chemical composition to the extent that animals preferred plants growing on one soil type over the other. Bitterbrush utilization was 50% greater on plants growing on the Grainola soil than plants on the Lucien soil. Due to the small sample (plants/soil type) size, comparisons of preference (utilization) by site may not be a true indication of preference.

Species Growth, Survival, and Utilization

Species growth, survival, and utilization varied greatly among species (Fig. 6). Average mid-range growth ranged from 7 cm for Jersey tea to 30 cm for Apache-plume. Fourwing saltbush, cliffrose, Apache-plume, and bitterbrush produced mean growth of 15 cm or more.

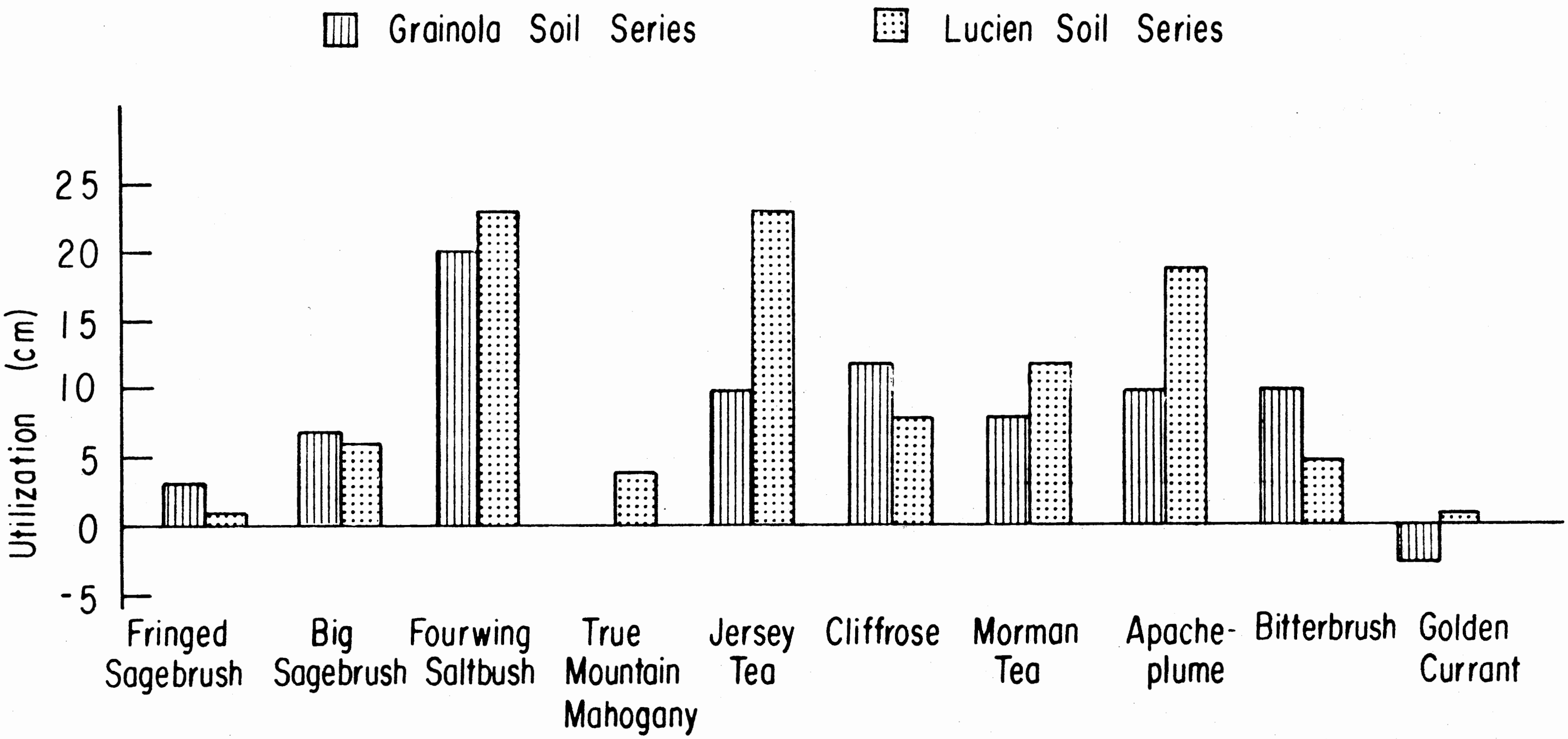
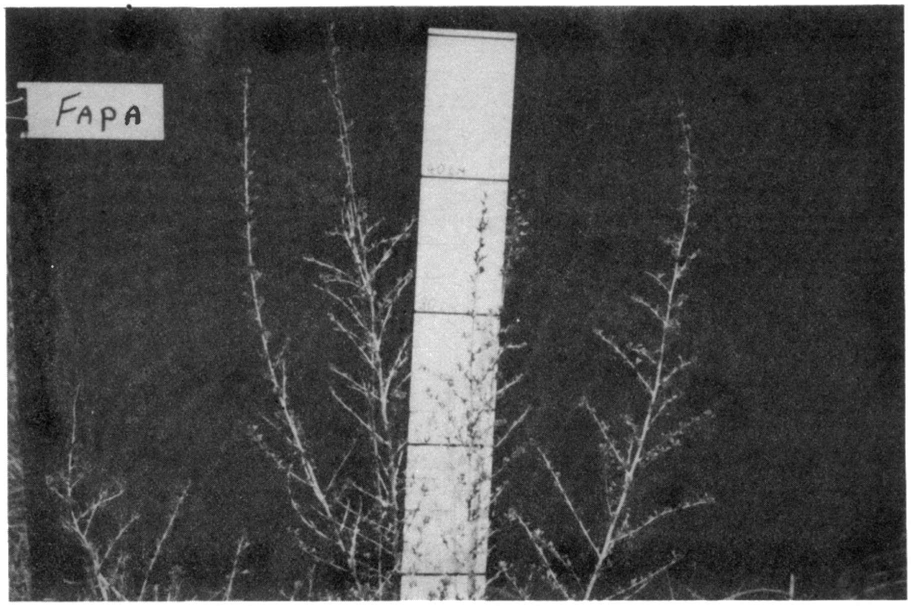
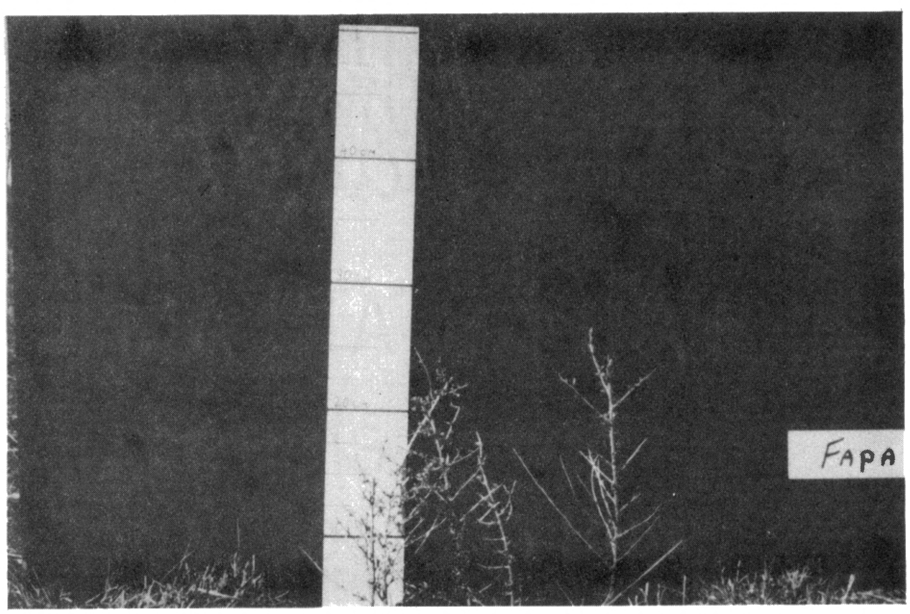


Fig. 4. Mid-range fall utilization (cm) averages of 10 introduced shrub species on 2 soild types. Negative utilization indicates species lost leaves during summer but not browsed during the fall.



(A)



(B)

Fig. 5. Apache-plume in September before browsing (A) and in November after browsing (B).

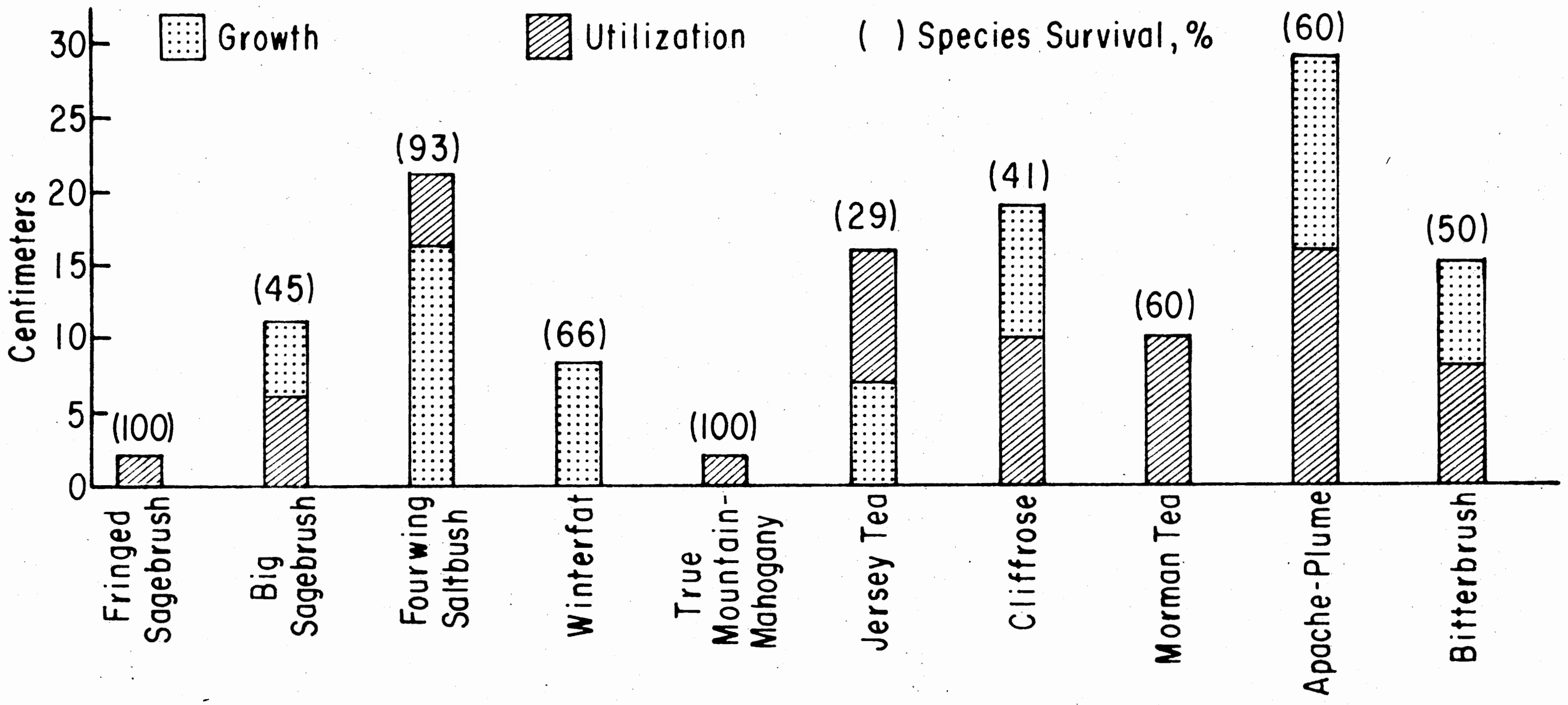


Fig. 6. Summer growth, fall utilization, and species survival of 10 introduced browse species. Initial transplanted growth as well as new growth was consumed where utilization exceeds growth.

Big sagebrush, winterfat, Jersey tea, and Morman tea grew less than 15 cm.

Shadscale, snowbrush, shrubby cinquefoil, and wedgeleaf ceanothus failed to survive the summer. Apparently climatic differences between the study area and the native habitat of these species were too great for survival even though the plants were watered. No common habitat requirements or limitation for these 4 species could be determined from the literature.

Species survival ranged from a low of 29% for Jersey tea to a high of 100% for fringed sagebrush and true mountain-mahogany. Well developed root systems of fringed sagebrush and true mountain-mahogany when transplanted probably enabled them to survive the high summer temperatures and soil water stress. Big sagebrush, Jersey tea, and cliffrose survival was less then 50%, whereas, survival of fringed sagebrush, fourwing saltbush, winterfat, true mountain-mahogany, Morman tea, Apache-plume, and bitterbrush was 50% or greater.

Utilization of fringed sagebrush and true mountain-mahogany was relatively low. Utilization of new growth was approximately 50% for big sagebrush, cliffrose, Apache-plume, and bitterbrush. Both leaves and stems of big sagebrush were browsed. Often entire plants were stripped of their leaves.

Fourwing saltbush utilization exceeded new growth by 5 cm (31%). Not only was new growth consumed but part of the original plant growth was eaten. All fourwing saltbush plants were heavily utilized. Winterfat plants were too few to determine utilization.

Utilization of Jersey tea plants exceeded new growth by 9 cm (125%). Many plants were either chewed off at ground level or missing.

Morman tea plants failed to produce new growth but almost all old growth was consumed.

Plant Chemical Composition and Digestibility

Plant chemical composition in November was determined on a dry weight basis from a compositie sample for each species. Nitrogen, phosphorus, potassium, and calcium contents varied greatly among species. The variation of NBDMD among species was less pronounced than chemical composition (Table 2).

Nitrogen content in the various species ranged from 0.89 to 2.5%, phosphorus 0.07 to 0.23%, potassium 0.52 to 1.48%, and calcium 0.58 to 1.99%. The high nitrogen content in true mountain-mahogany plants may be due, in part, to the high percentage of leaves in the sample. This species produced very little woody stem growth but an abundance of leaves. At the time of sampling, leaves were greenish brown in color, flexible, and intact. This species appears to have a greater cold tolerance than other species; therefore translocation of nutrients from leaves to stems may occur later in the season. There was insufficient plant sample to determine nitrogen content of Jersey tea and winterfat. High levels of calcium accumulated by some plants may be due to the $CaCO_3$ added to the potting mixture. Soils on the study area were not unusually high in calcium.

In most instances fall nutrient contents of study species were lower than reported levels for these species growing in their native habitat. The nutrient contents of study species was much greater than nutrient levels in herbaceous samples collected in the study area.

Table 2. Fall chemical composition (%) and nylon bag dry matter digestibility (%) for introduced shrubs.

Species	N	P	K	Ca	NBDMD (%) (N=3 Animals) ($\bar{x} \pm$ sd)	NBDMD (%) (N=2 Animals) ($\bar{x} \pm$ sd)
Fourwing Saltbush	1.00	.17	1.48	.99	35 ± 11	47 ± 7
Big Sagebrush	1.93	.18	1.25	.62	32 ± 21	50 ± 2
Cliffrose	.92	.14	.87	.80	42 ± 9	53 ± 2
Apache-plume	1.16	.14	.69	1.37	32 ± 14	46 ± 3
Bitterbrush	.89	.12	.52	.68	37 ± 12	50 ± 2
Fringed Sagebrush	1.38	.14	1.14	.58		
True Mountain-Mahogany	2.50	.23	.75	.79		
Morman Tea	1.56	.17	1.25	2.00		
Golden Currant	1.18	.19	1.17	.99		
Jersey Tea	1/	.07	.46	1.18		
Winterfat	1/	.17	.79	.88		

1/ Insufficient sample for nitrogen determination.

Mean nutrient contents for study species were nitrogen 1.39%, phosphorus 0.15%, potassium 0.85%, and calcium 0.99%. Mean nitrogen content of prairie hay samples cut at the same time was 0.57%. Phosphorus, potassium, and calcium levels of forage cut at the same time from a comparable area was 0.04%, 0.36%, and 0.44%, respectively.

Study species were relatively digestible. Digestibility of study species ranged from 46 to 53% or 32 to 42% depending on whether data from the 2 steers with comparable digestibility values or data from all three steers were used. At the time of NBDMD determinations one research animal was listless and losing weight. Values from digestibility trials in this animal were consistently lower than values from the other two animals. Insufficient plant material was available to repeat the trials.

There was not enough plant sample to determine NBDMD for fringed sagebrush, true mountain-mahogany, Morman tea, golden currant, Jersey tea, or winterfat. Mean NBDMD of all study species was 35% with 3 steers and 49% with 2 steers. Digestibility of forage samples collected from the study area at the same time was only 22%.

Conclusions

Plant growth and survival for most species was greater on the more mesic Grainola soil, while utilization was usually greater on the xeric Lucien soil. Big sagebrush, fourwing saltbush, and Apache-plume growth was not affected by soil type and these species have a good potential as browse plants in the tallgrass prairie. Fringed sagebrush and true mountain-mahogany also seem to be potential browse plants in this area. Curlleaf mountain-mahogany, Morman tea, and golden currant did not grow well on either soil type and their successful establishment and growth are doubtful. Fourwing saltbush, cliffrose, Apache-plume, and bitterbrush made the greatest growth. Fourwing saltbush, Jersey tea, and Apache-plume were the most heavily browsed and would increase diet diversity. Fringed sagebrush, true mountain-mahogany, fourwing saltbush, winterfat, and Apache-plume had the highest survival percentage.

Based on growth, utilization, survival, and chemical composition, further work towards establishment of fourwing saltbush and Apache-plume in tall grass prairie is recommended. It appears critical that grazing be completely deferred until after the second growing season to allow for establishment. Transplant sites such as earthen dams and shelter belts are areas which could be easily protected from grazing. If plastic containers are used they should be removed early in the second growing season.

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APPENDIX A

COMMENT 1977

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TITLE 'STIDHAM SHRUB STUDY';

COMMENT 1977

  CHEMICAL SCARIFICATION, STRATIFICATION, AND SOAKING SEEDS IN A THIOUREA
    SOLUTION WERE TREATMENTS USED IN ATTEMPT TO GERMINATE SEEDS OF FOLLOWING
    SPECIES
      PUTR = PURSHIA TRIDENTATA  ATCA = ATRIPLEX CANESCENS
      CEOV = CEANOTHUS OVATUS  AMAL = AMELANCHIER ALNIFOLIA
      ARTR = ARTEMISIA TRIDENTATA  ATCO = ATRIPLEX CONFERTIFOLIA
      CEVE = CEANOTHUS VELUTINUS  CELA = CERATOIDES LANATA
      COME = COWANIA MEXICANA STANSBURIANA  EPVI = EPHEDRA VIRIDUS
      FAPA = FALLUGIA PARADOXA  KOPR = KOCHIA PROSTRATA
      POFR = POTENTILLA FRUTICOSA  RIAU = RIBES AUREUM  ROWO = ROSA WOODSII
      CECU = CEANOTHUS CUNEATUS  ADFA = ADENOSTOMA FASCICULATUM
      CELE = CERCOCARPUS LEDIFOLIUS

  ALL TREATMENTS WERE REPLICATED 3 TIMES WITH 25 SEEDS IN EACH REP
    VERMICULITE WAS USED AS THE SUBSTRATE AND COVERING FOR ALL STUDIES
    GERMINATOR WAS SET FOR ALTERNATING TEMP OF 12.5 C (NIGHT) AND 20 C (DAY)
    FOR 16 AND 8 HR RESPECTFULLY
    A SEED WAS CONSIDERED GERMINATED WHEN EITHER THE SEED OR RADICAL WAS PUSHED
    UP THROUGH THE VERMICULITE
    SEEDLINGS WERE COUNTED EACH MON, WED, AND FRI FOR 4 WEEKS

  CHEMICAL SCARIFICATION
    CHEM USED FOR SCAR WERE CONC SULFURIC ACID, HYDROGEN PEROXIDE AND CHLOROX
    EACH ACID WAS USED IN FOUR TIME-INTERVAL TREATMENTS OF 12, 9, 6, 3, AND 0 HR

  STRATIFICATION
    DISTILLED WATER AND A 2% SOL OF KNIT WERE USED AS MOISTENING AGENTS
    BITTERBRUSH, FOURWING SALTBUSH, AND INLAND CEANOTHUS WERE STRATIFIED FOR
    16, 8, 2, AND 0 WKS
    ALL OTHER SPECIES WERE STRATIFIED FOR 10, 2, AND 0 WKS
    GERM BOXES WERE TAPED SHUT AND PLACED IN DARK COLD STORAGE AT 3C

  THIOUREA
    SEED WERE SOAKED IN A 3% SOLUTION OF THIOUREA AT 4 TIME-INTERVAL TMTS OF
    60, 40, 20, AND 0 MINUTES

  GREENHOUSE
    MULTIPLE SEEDLINGS OF EACH SP WERE TRANSPLANTED INTO LARGE POTS AND MOVED
    TO THE GREENHOUSE
    POTS WERE PLACED IN LARGE ALUMINUM FLATS AND FLOODED TO ALLOW PLANTS TO
    DRAW WATER UP FROM BELOW
    SEEDLINGS WERE FERTILIZED WITH A 18-26-16 AND WATERED AS NEEDED

  FIELD DATA
    THE LARGEST AND SMALLEST PLANTS IN EACH POT WERE MEASURED AND RECORDED AS
    WELL AS THE NUMBER OF LIVE PLANTS BEFORE TRANSPLANTING ONTO THE STUDY AREA
    ALL PLANTS WERE TRANSPLANTED ONTO THE STILLWATER CREEK EXP RANGE LOCATED
    17 KM WEST OF STILLWATER OK IN PAYNE CO ON APRIL FIRST
    THE SPECIES WERE EVENLY DIVIDED OVER TWO LOAMY PRAIRIE RANGE SITES
    ALL POTS WERE COVERED WITH MAMMAL GRAZE PROOF CAGES
    PLANTS WERE FERTILIZED AND WATERED AS NEEDED THROUGHOUT THE SEASON
    SOIL SAMPLES WERE TAKEN AT 15CM INCREMENTS AT 3 LOCATIONS ON EACH SOIL TYPE
    AND WET SOIL WEIGHTS DETERMINED IN THE FIELD

  SEPT
    SEPT 1 ONE-HALF OF THE CAGES ON EACH SPECIES ON EACH SITE WERE REMOVED TO
    ALLOW GRAZING
    THE LARGEST AND SMALLEST PLANTS IN ALL POTS WERE MEASURED AND RECORDED AT
    THIS TIME AS WELL AS THE NUMBER OF LIVE PLANTS

  FROST
    AFTER THE FIRST KILLING FREEZE THE LARGEST AND SMALLEST PLANTS IN ALL CAGED
    AND UNCAGED POTS WERE MEASURED AND RECORDED AS WELL AS NUMBER OF LIVE PLANTS
    ALL PLANTS IN THE REMAINING CAGES WERE CLIPPED FOR CHEMICAL ANALYSIS

  NOV 20
    LARGEST AND SMALLEST PLANTS IN EACH POT UNCAGED SEPT 1 WERE MEASURED AND
    NUMBER OF LIVE PLANTS WERE RECORDED
    FALL UTILIZATION WAS DETERMINED FROM THESE SAMPLES

  WEATHER
    SOIL TEMPERATURE WAS TAKEN INSIDE AND OUTSIDE CAGES AT EACH SAMPLING PERIOD
    CLOUD COVER DEW WIND VELOCITY DIRECTION AND WET AND DRY BULB READINGS FROM
    A SLING PSYCHROMETER WERE MADE EVERY 30 MIN EACH SAMPLING PERIOD

  LABORATORY ANALYSIS
    SOIL AND PLANT SAMPLES WERE AIR DRIED FOR 10 DAYS AT ROOM TEMPERATURE AND
    DRY WEIGHTS RECORDED AND THEN SAMPLES WERE GROUND FOR CHEMICAL ANALYSIS
    SURFACE SOIL SAMPLES WERE ANALYZED FOR SAND SILT CLAY PH OM N P K CA NA MG
    SUBSURFACE SAMPLES WERE ANALYZED FOR SAND SILT CLAY PH AND OM
    PLANT SAMPLES WERE ANALYZED FOR KJELDAHL NITROGEN CALCIUM PHOSPHORUS AND
    POTASSIUM
    PERCENT DRY MATTER WAS DETERMINED BY HEATING A 2GM SAMPLE AT 100C FOR 24 HR
    INVIVO DMD DETERMINATIONS WERE MADE FOR PLANT SAMPLES BY PLACING THREE 3GM
    SAMPLES IN 3 RUMEN FISTULATED STEERS FOR 48 HOURS;
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APPENDIX B

SPECIES SELECTED FOR STUDY

Table 1. Common and scientific names and species code for study species.

Shrubs	Genus Species [1]	Species Code
Apache-plume	*Fallugia paradoxa* (D.Don) Endl.	Fapa
Big sagebrush	*Artemisia tridentata* Nutt.	Artr
Bitterbrush	*Purshia tridentata* (Pursh) DC	Putr
Chamise	*Adenostoma facsiculatum* H. & A [2]	Adfa
Cliffrose	*Cowania mexicana* var. *stansburiana* (Torr.) Jespen	Come
Curlleaf mountainmahogany	*Cercocarpus ledifolius* Nutt.	Cele
Fringed sagebrush	*Artemisia frigida* Willd.	Arfr
Fourwing saltbush	*Atriplex canescens* (Pursh) Nutt.	Atca
Golden currant	*Ribes aureum* Pursh	Riau
Inland Jersey tea	*Ceanothus ovatus* Desf. [2]	Ceov
Morman tea	*Ephedra viridis* Cov.	Epvi
Prostrate kochia	*Kochia prostrata* (L). Schrad.	Kopr
Serviceberry	*Amelanchier alnifolia* Nutt.	Amal
Shadscale	*Atriplex confertifolia* (Torr. & Frem.) S. Watts	Atco
Shrubby cinquefoil	*Potentilla fruticosa* L.	Pofr
Snowbrush	*Ceanothus velutinus* Dougl.	Ceve
True mountainmahogany	*Cercocarpus montanus* Raf.	Cemo
Wedgeleaf ceanothus	*Ceanothus cuneatus* (Hook.) Nutt.	Cecu
Winterfat	*Ceratoides lanata*	Cela
Woods rose	*Rosa woodsii* Lindl.	Rowo

1/ Scientific nomenclature according to USDA Forest Service 1977.

2/ Scientific nomenclature according to Soil Conservation Service 1971.

APPENDIX C

SOURCE AND PURE SEED OF STUDY SPECIES

Table 1. Source collection date, and pure seed (%) of each species used in chemical scarification and prechill studies.

Species	Source	Collection Date	Identification Number	Pure Seed 1/
Putr	Sharp Bros. Seed Co.			100
Atca	Sharp Bros. Seed Co.			80
Ceov	P.M.C., Manhatten, Kan.	1975	PMK-1383	100
Amal	Soda Springs, Idaho	9/76	LK-405	100
Artr	Gordon Creek, Price, Utah	1975	U41-75	100
Atco	Rio Blanco Co., Colo.	9/75	EPC-211	80
Ceve	Sawtooth Nat. For., Gooding, Idaho	1966	U2-66	76
Cela	Rio Blanco Co., Colo.	9/75	EPC-214	100
Cele	Juniper Mtn., Idaho	1974	U41-74	96
Come	Mona, Utah	1973	U21-73	100
Epvi	Rio Blanco Co., Colo.	8/75	EPC-58	100
Fapa	San Luis Valley, Colo.	10/75	EPC-580	100
Kopr	P.M.C., Aberdeen, Idaho	1974	AB-495	88
Pofr	College Farm, Ephraim, Utah	1974	U1-74	100
Riau	Aberdeen, Idaho	8/76	AB-787	100
Rowo	Summit Co., Colo.	9/75	EPC-405	80
Cecu	P.M.C., Lockford, Calif.	9/76	P1-84-71	100
Adfa	Mt. Diablo, Calif.	8/76	P1-40-71	96

1/ Well filled complete seed units.

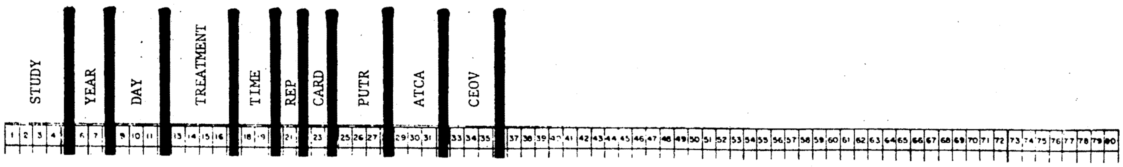
Table 2. Source, collection date, and pure seed (%) of each species used in thiourea studies.

Species Code		Collection Date	Identification Number	Pure Seed 2/
Putr	Rio Blanco Co., Colo.	8/75	IPC-132	100
Atca	Rio Blanco Co., Colo.	11/75	EPC-512	84
Ceov	P.M.C., Manhattan Kansas	1975	PMK-1383	100
Amal	Rio Blanco Co., Colo.	9/75	EPC-393	100
Artr	Gordon Creek, Price, Utah	1975	U41-75	100
Atco	Enoch, Utah	9/74	Ab-744	26
Ceve	Rio Blanco Co., Colo.	9/75	EPC-243	48
Cela	Kanab, Utah	11/75	Ab-764	92
Come	Redfield, Utah	8/75	Ab-743	100
Epvi	Rio Blanco Co., Colo.	8/75	EPC-58	100
Fapa	Richfield, Utah	1974	U1-74	92
Kopr	College Farm, Ephraim, Utah	1974	U2-74	96
Pofr	College Farm, Ephraim, Utah	1974	U1-74	100
Riau	Malad, Idaho	1972	U15-72	100
Rowo	Summit Co., Colo.	9/75	EPC-405	80
Cecu	Siskiuou Co., Calif.	1971	U6-71	100
Adfa	Mt. Diablo, Calif.	8/76	P1-SO-71	96

2/ Well filled complete seed units.

APPENDIX D

CHEMICAL SCARIFICATION DATA SHEET, INPUT, COMMENT, COMPUTER PROGRAM STATEMENTS, GERMINATION MEANS, AND WEEKLY MEAN GERMINATION FIGURES




```
TITLE 'STIDHAM SHRUB STUDY';
DATA CHEMSC; INPUT
  STUDY $ 1-4 YR 6-7 DAY 9-11 TRT $ 13-16 TIM 18-19 REP 21 CD 23
  PUTR 25-27 ATCA 29-31 CEOV 33-35;
  PUTR=PUTR + 0; ATCA=ATCA + 0; CEOV=CEOV + 0;



COMMENT
  STUDY = CHEMICAL (ACID) SCARIFICATION
    DAY AND YEAR  10/7/76 THRU 10/28/76
    TREATMENT = CHEMICALS USED FOR SCARIFICATION AND CONTROL (DISTILLED WATER)
      CHLOROX HYDROGEN PEROXIDE AND CONC SULFURIC ACID
    TIME = LENGTH OF SCARIFICATION 0-NO PRETREATMENT 3-HR 6-HR 9-HR AND 12-HR
    REPLICATION = 3 REPLICATIONS FOR ALL TREATMENTS AND TIMES
    CARD = DATA CARD NUMBER
    PUTR = PURSHIA TRIDENTATA ATCA = ATRIPLEX CANESCENS CEOV = CEANOTHUS OVATUS;


PROC SORT OUT=SHRUBS DATA=CHEMSC; BY DAY TRT TIM REP;



PROC ANOVA DATA = CHEMSC; BY DAY;
  CLASSES REP TRT TIM; MEANS REP|TRT|TIM;
  MODEL PUTR ATCA CEOV = REP TRT|TIM;
    POOL 'TI' RESIDUAL/TIM;
    POOL 'TR' RESIDUAL/TRT;
    POOL 'TT' RESIDUAL/TIM*TRT;
    TEST TIM|TRT BY 'TT';



DATA SET CHEMSC

CLASSES        VALUES

REP            1 2 3

TRT            CHLO HYPR SULF

TIM            3 6 9 12
```

Table 1. Mean germination of 3 reps. for 3 browse species at 14, 21, and 28 days germination. Species were scarified with 3 chemicals for 4 time interval treatments.

	Germination							
	14		21			28		
Species	Bitterbrush	Fourwing Saltbush	Bitterbrush	Fourwing Saltbush	Jersey Tea	Bitterbrush	Fourwing Saltbush	Jersey Tea
Time (hours)								
3	0.33 a[1]	7.33 c	1.66 a	8.33 c	2.00 a	2.00 ab	8.66 c	2.33 a
6	1.00 b	6.00 bc	1.33 a	6.66 b	2.33 a	2.66 b	6.66 b	2.33 a
9	0.33 a	5.33 ab	1.66 a	5.33 ab	3.33 b	2.00 ab	5.33 a	4.00 b
12	-- [2]a	4.44 a	1.33 a	4.44 a	1.66 a	1.66 a	4.44 a	2.00 a
Treatment (chemical)								
Chlorox	-- a	4.75 b	1.75 b	5.75 b	2.50 b	2.50 b	6.00 b	3.25 b
Hydrogen Peroxide	1.25 b	11.83 c	2.75 c	12.08 c	4.50 c	3.75 c	12.08 c	4.75 c
Sulfuric Acid	-- a	0.75 a	-- a	0.75 a	-- a	-- a	0.75 a	-- a
Treatment X Time								
Chlo 3	-- a	7.00 c	2.00 bc	9.00 c	2.00 b	3.00 b	10.00 cd	3.00 b
Chlo 6	-- a	9.00 c	1.00 ab	11.00 cd	3.00 bc	2.00 b	11.00 cde	3.00 b
Chlo 9	-- a	2.00 ab	3.00 c	2.00 ab	3.00 bc	3.00 b	2.00 ab	4.00 b
Chlo 12	-- a	1.00 ab	1.00 ab	1.00 ab	2.00 b	2.00 b	1.00 ab	3.00 b
Hypr 3	1.00 b	12.00 d	3.00 c	13.00 de	4.00 c	3.00 b	13.00 ef	4.00 b
Hypr 6	3.00 c	9.00 c	3.00 c	9.00 c	4.00 c	6.00 c	9.00 c	4.00 b
Hypr 9	1.00 b	14.00 d	2.00 bc	14.00 e	7.00 d	3.00 b	14.00 f	8.00 c
Hypr 12	-- a	12.33 d	3.00 c	12.33 de	3.00 bc	3.00 b	12.33 def	3.00 b
Sulf 3	-- a	3.00 b	-- a	3.00 b	-- a	-- a	3.00 b	-- a
Sulf 6	-- a	-- a	-- a	-- a	-- a	-- a	-- a	-- a
Sulf 9	-- a	-- a	-- a	-- a	-- a	-- a	-- a	-- a
Sulf 12	-- a	-- a	-- a	-- a	-- a	-- a	-- a	-- a
$LSD_{.05}$ Time	.40	1.30	.65	1.30	.97	.83	1.16	.80
$LSD_{.05}$ Treatment	.35	1.13	.57	1.12	.84	.72	1.00	.70
$LSD_{.05}$ Treatment X Time	.70	2.25	1.13	2.24	1.67	1.44	2.00	1.39

[1]Means in the same column followed by a similar letter are not significantly different at the .05 level of probability.

[2]No germination.

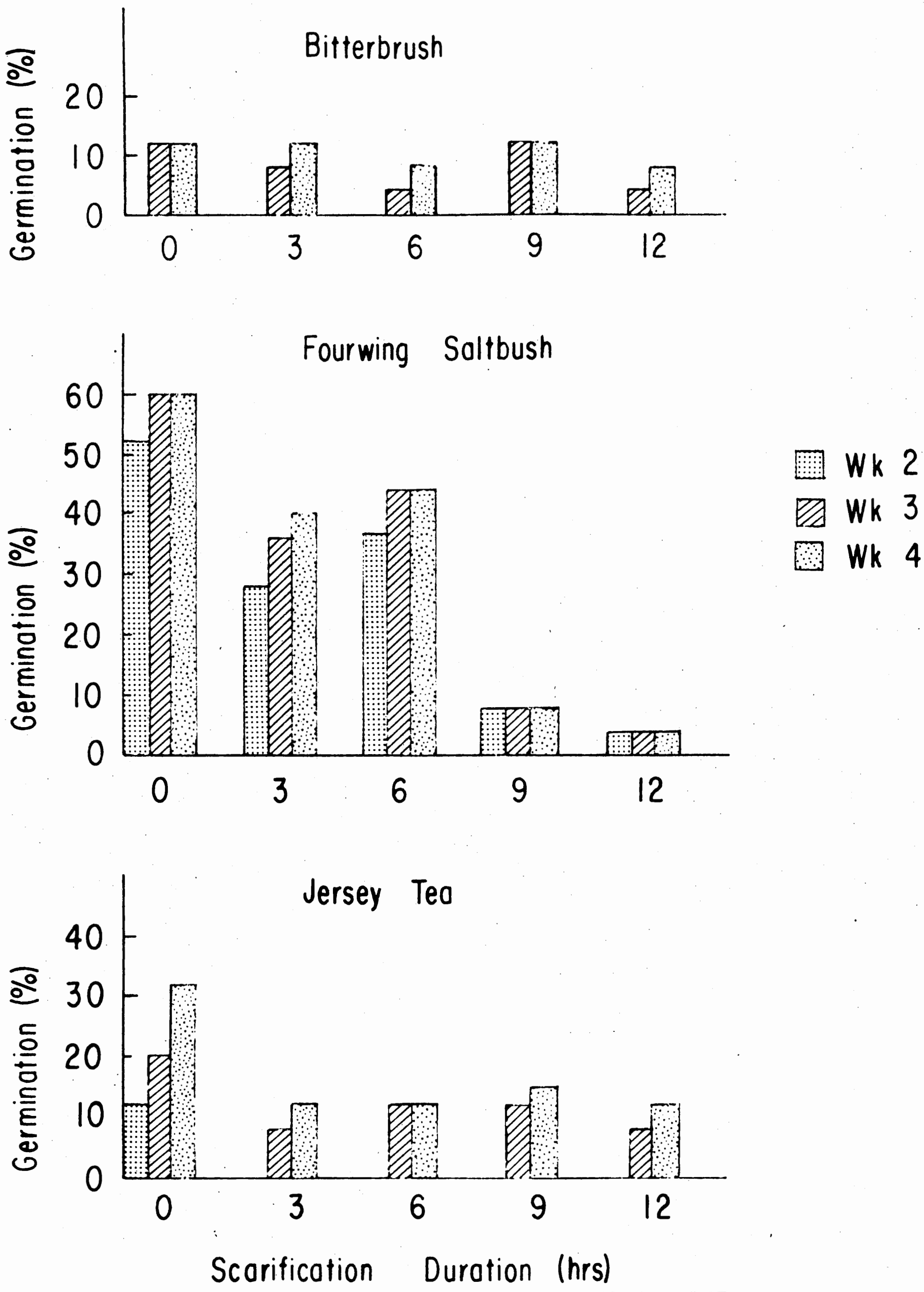


Figure 1. Weekly mean germination (%) of 3 browse species scarified in different clorox time treatments prior to germination.

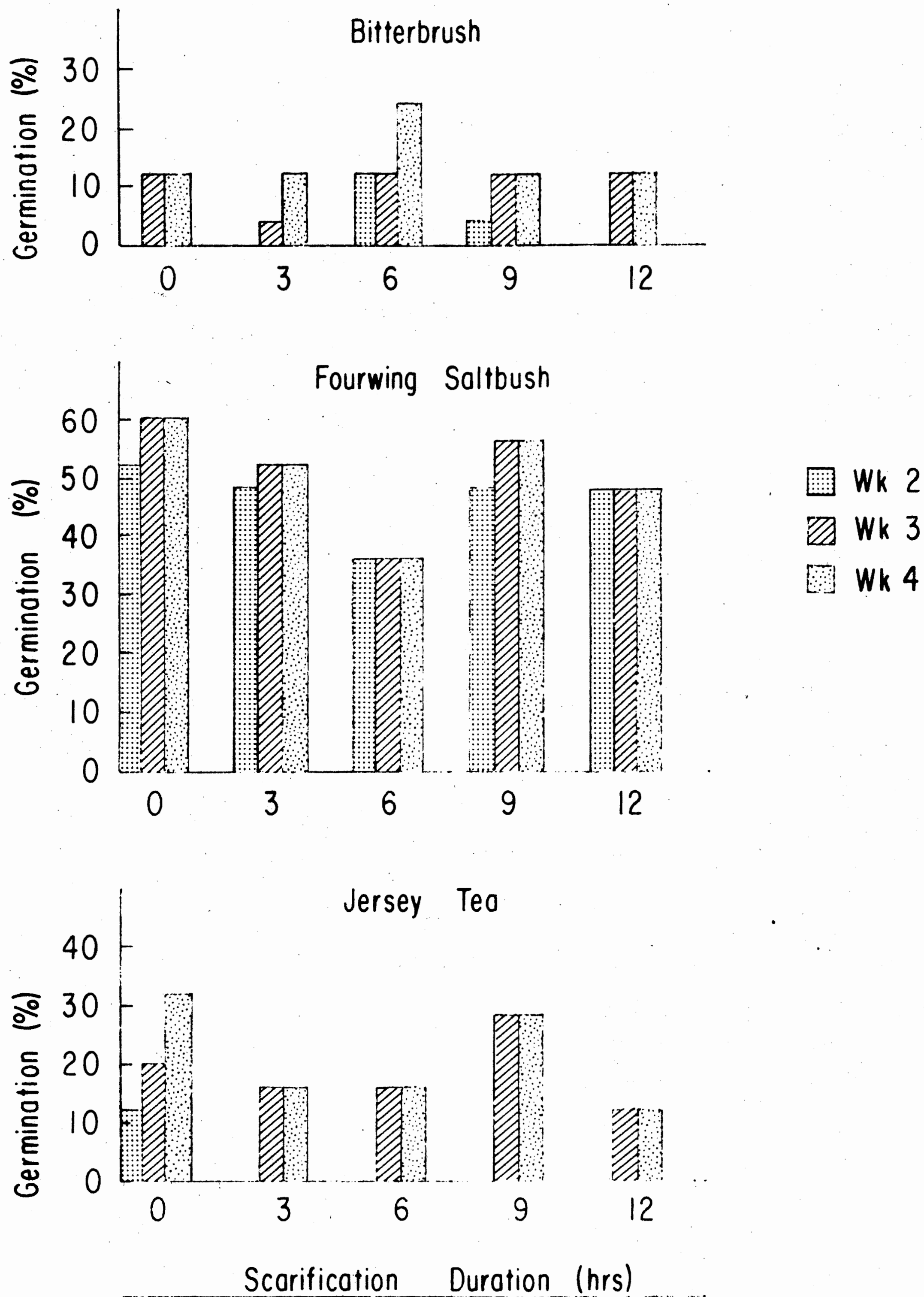
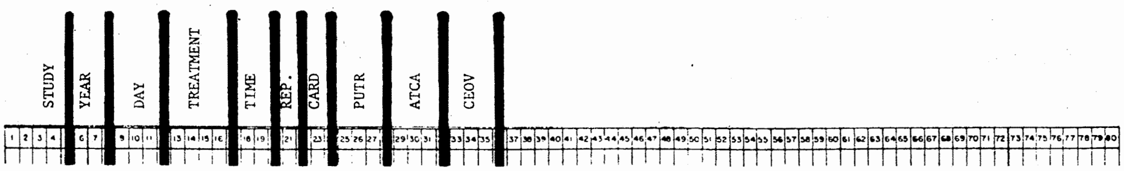


Figure 2. Weekly mean germination (%) of 3 browse species scarified in different hydrogen peroxide time treatments prior to germination.

APPENDIX E

PRELIMINARY PRECHILL STUDY DATA SHEET, INPUT, COMMENT, COMPUTER PROGRAM STATEMENTS, GERMINATION MEANS, AND WEEKLY GERMINATION FIGURES




```
TITLE 'STIDHAM SHRUB STUDY';
DATA STRT1; INPUT
  STUDY $ 1-4 YR 6-7 DAY 9-11 TRT $ 13-16 TIM 18-19 REP 21 CD 23
  PUTR 25-27 ATCA 29-31 CEOV 33-35;
  PUTR=PUTR+0; ATCA=ATCA+0; CEOV=CEOV +0;
```

```
COMMENT
  STUDY = STRATIFICATION 1 (PRECHILL) 3 SPECIES
    DAY AND YEAR = 8/22/76 THRU 9/12/76
    TREATMENT = PRECHILL MOISTENING AGENT DIST = DISTILLED WATER
      KNIT (KNO3) = 2% POTASSIUM NITRATE SOLUTION
    TIME = LENGTH OF PRECHILL 0-WKS 2-WKS 8-WKS AND 16-WKS
    REPLICATION = 3 REPLICATIONS FOR ALL TREATMENTS AND TIMES
    CARD = DATA CARD NUMBER
    PUTR = PURSHIA TRIDENTATA ATCA = ATRIPLEX CANESCENS CEOV = CEANOTHUS OVATUS;
```

```
PROC ANOVA DATA = STRT1; BY DAY;
  CLASSES REP TRT; MEANS REP|TIM;
  MODEL CEOV = REP TRT|TIM;
    POOL 'TI' RESIDUAL/TIM;
    POOL 'TR' RESIDUAL/TRT;
    POOL 'TT' RESIDUAL/TIM*TRT;
    TEST TIM|TRT BY 'TT';
```

DATA SET STRT1

CLASSES	VALUES
REP	1 2 3
TRT	DIST KNIT
TIM	0 2 8 16

```
DATA STT02; SET STRT1; IF TIM = 0 OR TIM = 2;

PROC ANOVA DATA = STT02; BY DAY;
  CLASSES REP TRT; MEANS REP|TIM;
  MODEL PUTR ATCA CEOV = REP TRT|TIM;
    POOL 'TI' RESIDUAL/TIM;
    POOL 'TR' RESIDUAL/TRT;
    POOL 'TT' RESIDUAL/TIM*TRT;
    TEST TIM|TRT BY 'TT';

DATA SET STT02

CLASSES          VALUES

REP              1 2 3

TRT              DIST KNIT

TIM              0 2




DATA STRT8; SET STRT1; IF TIM = 8;


PROC ANOVA DATA = STRT8; BY DAY;
  CLASSES REP TRT; MEANS REP|TIM;
  MODEL PUTR ATCA = REP|TRT;
    POOL 'ERROR' REP*TRT/TRT;
    TEST TRT BY 'ERROR';


DATA SET STRT8

CLASSES          VALUES

REP              1 2 3

TRT              DIST KNIT

TIM              8



DATA STT16; SET STRT1; IF TIM = 16;

PROC ANOVA DATA = STT16; BY DAY;
  CLASSES REP TRT; MEANS REP|TIM;
  MODEL PUTR ATCA = REP|TRT;
    POOL 'ERROR' REP*TRT/TRT;
    TEST TRT BY 'ERROR';


DATA SET STT16

CLASSES          VALUES

REP              1 2 3

TRT              DIST KNIT

TIM              16
```

Table 1. Mean germination of 3 reps. for 3 browse species at 7, 14, 21 and 28 days germination. Species were prechilled for 0 and 2 weeks on vermiculite moistened with either distilled water or KNO_3.

	Germination							
	7		14		21		28	
Species	Bitterbrush	Fourwing Saltbush	Fourwing Saltbush	Jersey Tea	Fourwing Saltbush	Jersey Tea	Fourwing Saltbush	Jersey Tea
Time (weeks)								
0	0.16	3.50	9.50	4.50	9.83	10.33	9.83	10.33
2	0.83	9.66	12.50	13.16	12.83	14.16	12.83	14.16
Treatment (TRT)								
Distilled Water (D.W.)	0.66	5.83	11.16	7.83	11.83	11.83	11.83	11.83
KNO_3	0.33	7.33	10.83	9.83	10.83	12.66	10.83	12.66
Treatment X Time								
D.W. 0	0.33 a[1]	4.00 ab	9.66 a	3.66 a	10.33 a	10.33 a	10.33 a	10.33 a
D.W. 2	1.00 a	7.66 bc	12.66 a	12.00 a	13.33 a	13.33 a	13.33 a	13.33 a
KNO_3 0	--[2] a	3.00 a	9.33 a	5.33 a	9.33 a	10.33 a	9.33 a	10.33 a
KNO_3 2	0.66 a	11.66 c	12.33 a	14.33 a	12.33 a	15.00 a	12.33 a	15.00 a
Probability Level Time	.14	.01	.15	.01	.14	.09	.14	.09
Probability Level TRT	.56	.28	.86	.58	.60	.67	.60	.68
$LSD_{.05}$ TRT X Time	1.37	4.40	6.35	7.94	6.21	6.63	6.21	6.63

[1] Means in the same column followed by a similar letter are not significantly different at the .05 level of probability.

[2] No germination.

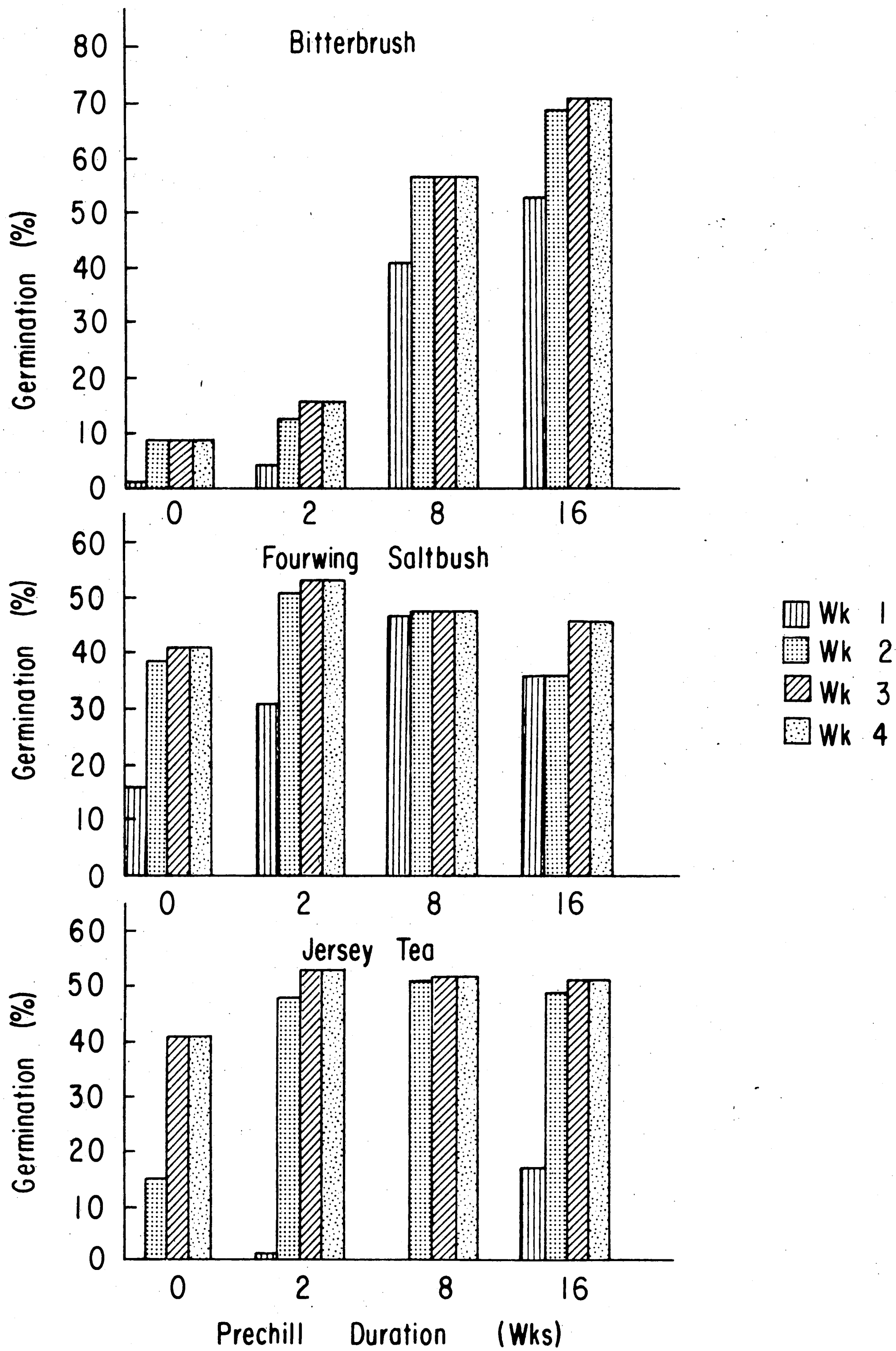


Figure 1. Weekly mean germination (%) of 3 browse species prechilled on substrate moistened with distilled water for 0, 2, 8, and 16 weeks prior to germination.

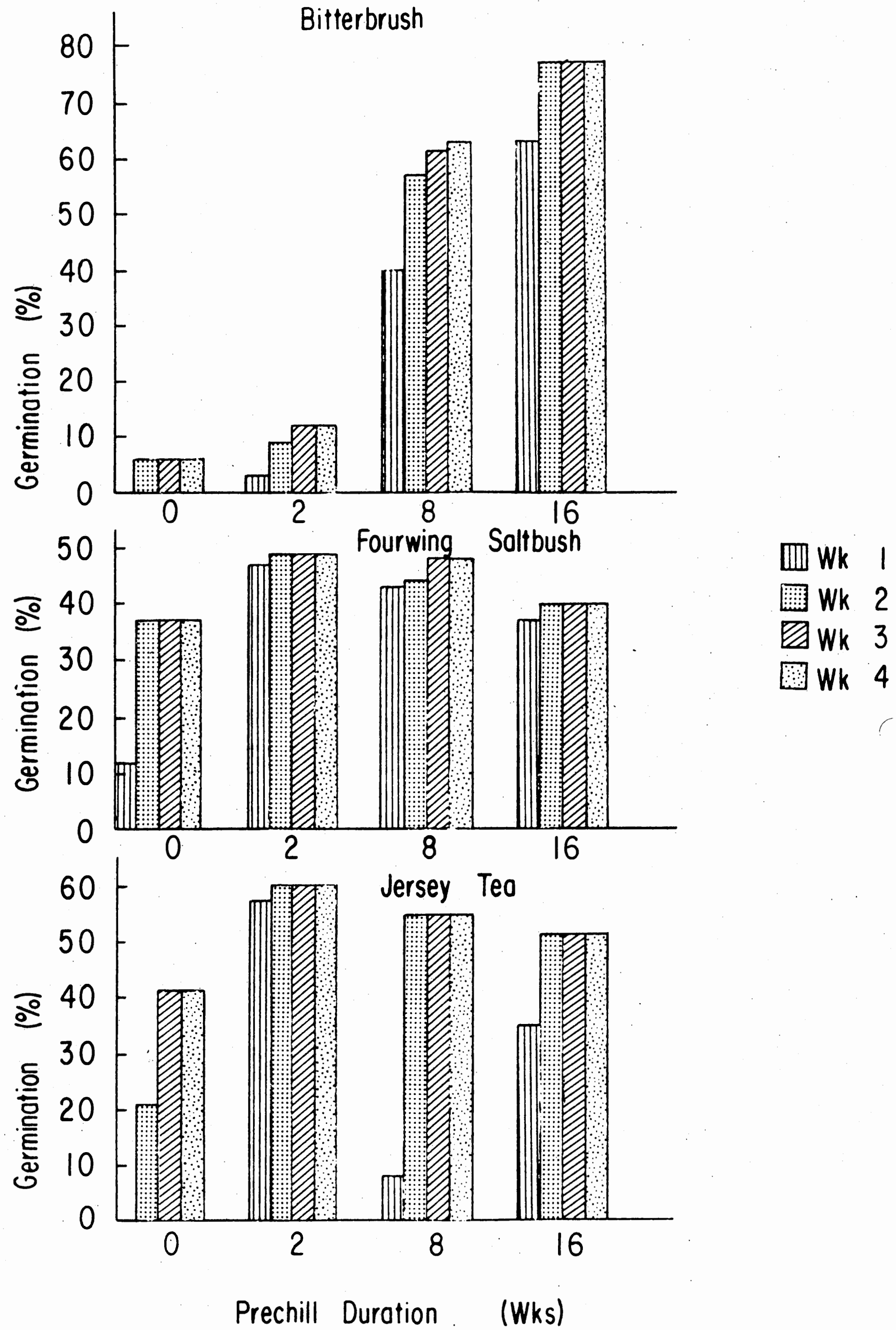
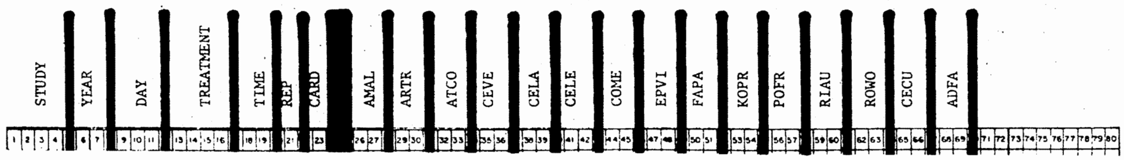


Figure 2. Weekly mean germination (%) of 3 browse species prechilled on substrate moistened with 0.2% KNO_3 solution for 0, 2, 8, and 16 weeks prior to germination.

APPENDIX F

PRECHILL DATA SHEET, INPUT, COMMENT, COMPUTER PROGRAM STATEMENTS, GERMINATION MEANS, AND WEEKLY GERMINATION FIGURES




```
TITLE 'STIDHAM SHRUB STUDY';
DATA STRT2; INPUT
   STUDY $ 1-4 YR 6-7 DAY 9-11 TRT $ 13-16 TIM 18-19 REP 21 CD 23
   AMAL 25-27 ARTR 29-30 ATCO 32-33 CEVE 35-36 CELA 38-39 CELE 41-42 COME 44-45
   EPVI 47-48 FAPA 50-51 KOPR 53-54 POFR 56-57 RIAU 59-60 ROWO 62-63 CECU 65-66
   ADFA 68-69;
   AMAL=AMAL + 0; ARTR=ARTR + 0; ATCO=ATCO + 0; CEVE=CEVE + 0; CELA=CELA + 0;
   CELE=CELE + 0; COME=COME + 0; EPVI=EPVI + 0; FAPA=FAPA + 0; KOPR=KOPR + 0;
   POFR=POFR + 0; RIAU=RIAU + 0; ROWO=ROWO + 0; CECU=CECU + 0; ADFA=ADFA + 0;


COMMENT
   STUDY = STRATIFICATION 2 (PRECHILL) 15 SPECIES
     DAY AND YEAR = 11/11/76 THRU 12/19/76
     TREATMENT = PRECHILL MOISTENING AGENT DIST = DISTILLED WATER
        KNIT (KNO3) = 2% POTASSIUM NITRATE SOLUTION
     TIME = LENGTH OF PRECHILL 0-WKS 2-WKS AND 10-WKS
     REPLICATION = 3 REPLICATIONS FOR ALL TREATMENTS AND TIMES
     CARD = DATA CARD NUMBER
     SPECIES
       AMAL = AMELANCHIER ALNIFOLIA  ARTR = ARTEMISIA TRIDENTATA
       ATCO = ATRIPLEX CONFERTIFOLIA  CEVE = CEANOTHUS VELUTINUS
       CELA = CERATOIDES LANATA  CELE = CERCOCARPUS LEDIFOLIUS
       COME = COWANIA MEXICANA STANSBURIANA  EPVI = EPHEDRA VIRIDUS
       FAPA = FALLUGIA PARADOXA  KOPR = KOCHIA PROSTRATA
       POFR = POTENTILLA FRUTICOSA  RIAU = RIBES AUREUM  ROWO = ROSA WOODSII
       CECU = CEANOTHUS CUNEATUS  ADFA = ADENOSTOMA FASCICULATUM;


PROC ANOVA DATA = STRT2; BY DAY;
  CLASSES REP TRT TIM; MEANS REP|TRT|TIM;
  MODEL AMAL ARTR ATCO CEVE CELA = REP TRT|TIM;
     POOL 'TI' RESIDUAL/TIM;
     POOL 'TR' RESIDUAL/TRT;
     POOL 'TT' RESIDUAL/TIM*TRT;
     TEST TIM|TRT BY 'TT';
```

DATA SET STRT2

CLASSES	VALUES
REP	1 2 3
TRT	DIST KNIT
TIM	0 2 10

Table 1. Mean germination of 3 reps. for 4 browse species at 7 days germination. Species were prechilled for 0, 2, and 10 weeks on vermiculite moistened with either distilled water or KNO_3.

Species	Big Sagebrush	Winterfat	Cliffrose	Morman Tea
Time (weeks)				
0	10.16 a[1]	3.66 b	--[2]a	.83 a
2	6.33 a	1.83 a	-- a	.66 a
10	20.83 b	.83 a	7.33 b	5.33 b
Treatment (TRT)				
Distilled water (D.W.)	14.44	3.22	1.22	2.44
KNO_3	10.44	1.00	3.66	2.11
Treatment X Time				
D.W. 0	15.00 bc	6.33 b	-- a	1.66 a
D.W. 2	8.33 ab	2.33 a	-- a	1.00 a
D.W. 10	20.00 c	1.00 a	3.66 a	4.66 b
KNO_3 0	5.33 a	1.00 a	-- a	-- a
KNO_3 2	4.33 a	1.33 a	-- a	0.33 a
KNO_3 10	21.66 c	.66 a	11.00 b	6.00 b
$LSD_{.05}$ Time	5.33	1.38	2.88	2.07
Probability Level TRT	.07	.01	.04	.67
$LSD_{.05}$ TRT X Time	7.82	1.95	4.08	2.93

[1]Means in the same column followed by a similar letter are not significantly different at the .05 level of probability.

[2]No germination.

Table 2. Mean germination of 3 reps. for 8 browse species at 14 days germination. Species were pre-chilled for 0, 2, and 10 weeks on vermiculite moistened with either distilled water or KNO_3.

Species	Big Sagebrush	Snowbrush	Winterfat	Curlleaf Mountain-Mahogany	Cliffrose	Morman Tea	Shrubby Cinquefoil	Golden Currant
Time (weeks)								
0	14.83 a[1]	--[2] a	3.66 b	-- a	-- a	7.50 a	7.16 a	0.66 a
2	13.83 a	0.16 a	1.83 a	-- a	0.50 a	9.50 a	9.83 ab	4.33 b
10	22.00 b	0.83 b	1.00 a	5.33 b	24.50 b	16.83 b	12.00 b	20.16 c
Treatment (TRT)								
Distilled water (D.W.)	17.00	0.22	3.22	1.00	8.00	12.33	10.77	8.22
KNO_3	16.77	0.44	1.11	2.55	8.66	10.22	8.55	8.55
Treatment X Time								
D.W. 0	16.33 a	-- a	6.33 a	-- a	-- a	11.66 b	8.66 ab	0.33 a
D.W. 2	13.66 a	-- a	2.33 a	-- a	-- a	10.66 ab	10.66 b	4.66 a
D.W. 10	21.00 a	0.66 a	1.00 a	3.00 b	24.00 b	14.66 bc	13.00 b	19.66 b
KNO_3 0	13.33 a	-- a	1.00 a	-- a	-- a	3.33 a	5.66 a	1.00 a
KNO_3 2	14.00 a	0.33 a	1.33 a	-- a	1.00 a	8.33 ab	9.00 ab	4.00 a
KNO_3 10	23.00 a	1.00 a	1.00 a	7.00 c	25.00 b	19.00 c	11.00 b	20.66 b
$LSD_{.05}$ Time	5.61	.70	1.35	1.14	.78	5.29	3.18	3.56
Probability Level TRT	.91	.59	.01	.01	.04	.30	.08	.80
$LSD_{.05}$ TRT X Time	7.94	1.00	1.90	1.61	1.10	7.48	4.49	5.03

[1]Means in the same column followed by a similar letter are not significantly different at the .05 level of probability.

[2]No germination.

Table 3. Mean germination of 3 reps. for 8 browse species at 21 days germination. Species were prechilled for 0, 2, and 10 weeks on vermiculite moistened with either distilled water or KNO_3.

Species	Sagebrush	Snowbrush	Winterfat	Curlleaf Mountain-Mahogany	Cliffrose	Morman Tea	Shrubby Cinquefoil	Golden Currant
Time (weeks)								
0	15.33 a[1]	--[2]a	3.66 b	-- a	0.33 a	13.83 a	10.50 a	7.16 a
2	15.00 a	0.16 a	1.83 a	-- a	2.50 b	14.83 a	14.50 b	16.33 b
10	22.16 b	1.83 b	1.00 a	6.66 b	24.83 c	20.00 b	13.50 b	23.33 c
Treatment (TRT)								
Distilled water (D.W.)	17.33	0.77	3.22	1.33	8.66	17.22	14.66	14.55
KNO_3	17.66	0.55	1.11	3.11	9.77	15.22	11.00	16.66
Treatment X Time								
D.W. 0	16.66 ab	-- a	6.33 b	-- a	-- a	17.00 bc	13.00 b	7.66 a
D.W. 2	14.00 a	-- a	2.33 a	-- a	1.33 a	15.66 abc	15.66 b	12.66 a
D.W. 10	21.33 ab	2.33 b	1.00 a	4.00 b	24.66 c	19.00 bc	15.33 b	23.33 b
KNO_3 0	14.00 a	-- a	1.00 a	-- a	0.66 a	10.66 a	8.00 a	6.66 a
KNO_3 2	16.00 ab	0.33 ab	1.33 a	-- a	3.66 b	14.00 ab	13.33 b	20.00 b
KNO_3 10	23.00 b	1.33 ab	1.00 a	9.00 c	25.00 c	21.00 c	11.66 ab	23.33 b
$LSD_{.05}$ Time	5.70	1.35	1.35	1.69	1.14	3.99	2.83	3.67
Probability Level TRT	.87	.67	.01	.02	.02	.20	.01	.14
$LSD_{.05}$ TRT X Time	8.06	1.90	1.90	2.39	1.61	5.64	4.00	5.18

[1]Means in the same column followed by a similar letter are not significantly different at the 0.5 level of probability.

[2]No germination.

Table 4. Mean germination of 3 reps. for 9 browse species at 28 days germination. Species were prechilled for 0, 2, and 10 weeks on vermiculite moistened with either distilled water or KNO_3.

Species	Big Sagebrush	Snowbrush	Winterfat	Curlleaf Mountain-Mahogany	Cliffrose	Morman Tea	Shrubby Cinquefoil	Golden Currant	Chamise
Time (weeks)									
0	15.66 a[1]	--[2] a	3.66 b	-- a	0.50 a	16.66 a	11.16 a	7.16 a	0.16 a
2	15.50 a	0.33 a	1.83 a	-- a	3.50 b	18.16 a	14.50 b	17.66 b	-- a
10	22.16 b	2.00 b	1.00 a	6.66 b	24.83 c	21.00 b	13.66 ab	23.50 c	0.83 b
Treatment (TRT)									
Distilled water (D.W.)	17.33	0.88	3.22	1.33	9.22	19.66	15.11	14.66	0.44
KNO_3	18.22	0.66	1.11	3.11	10.00	17.55	11.11	17.55	0.22
Treatment X Time									
D.W. 0	16.66 abc	-- a	6.33 b	-- a	-- a	19.66 b	14.00 b	7.66 a	0.33 a
D.W. 2	14.00 a	0.33 a	2.33 a	-- a	3.00 b	18.33 b	15.66 b	13,00 b	-- a
D.W. 10	21.33 abc	2.33 a	1.00 a	4.00 b	24.66 c	21.00 b	15.66 b	23.33 c	1.00 a
KNO_3 0	14.66 ab	-- a	1.00 a	-- a	1.00 a	13.66 a	8.33 a	6.66 a	-- a
KNO_3 2	17.00 abc	0.33 a	1.33 a	-- a	4.00 b	18.00 b	13.33 b	22.33 c	-- a
KNO_3 10	23.00 b	1.66 a	1.00 a	9.00 c	25.00 c	21.00 b	11.66 ab	23.66 c	0.66 a
$LSD_{.05}$ Time	5.30	1.36	1.35	1.69	1.30	2.60	3.07	3.22	.70
Probability Level TRT	.66	.66	.01	.02	.13	.05	.01	.03	.59
$LSD_{.05}$ TRT X Time	7.51	1.93	1.90	2.39	1.84	3.68	4.34	4.55	1.00

[1] Means in the same column followed by a similar letter are not significantly different at the .05 level of probability.

[2] No germination.

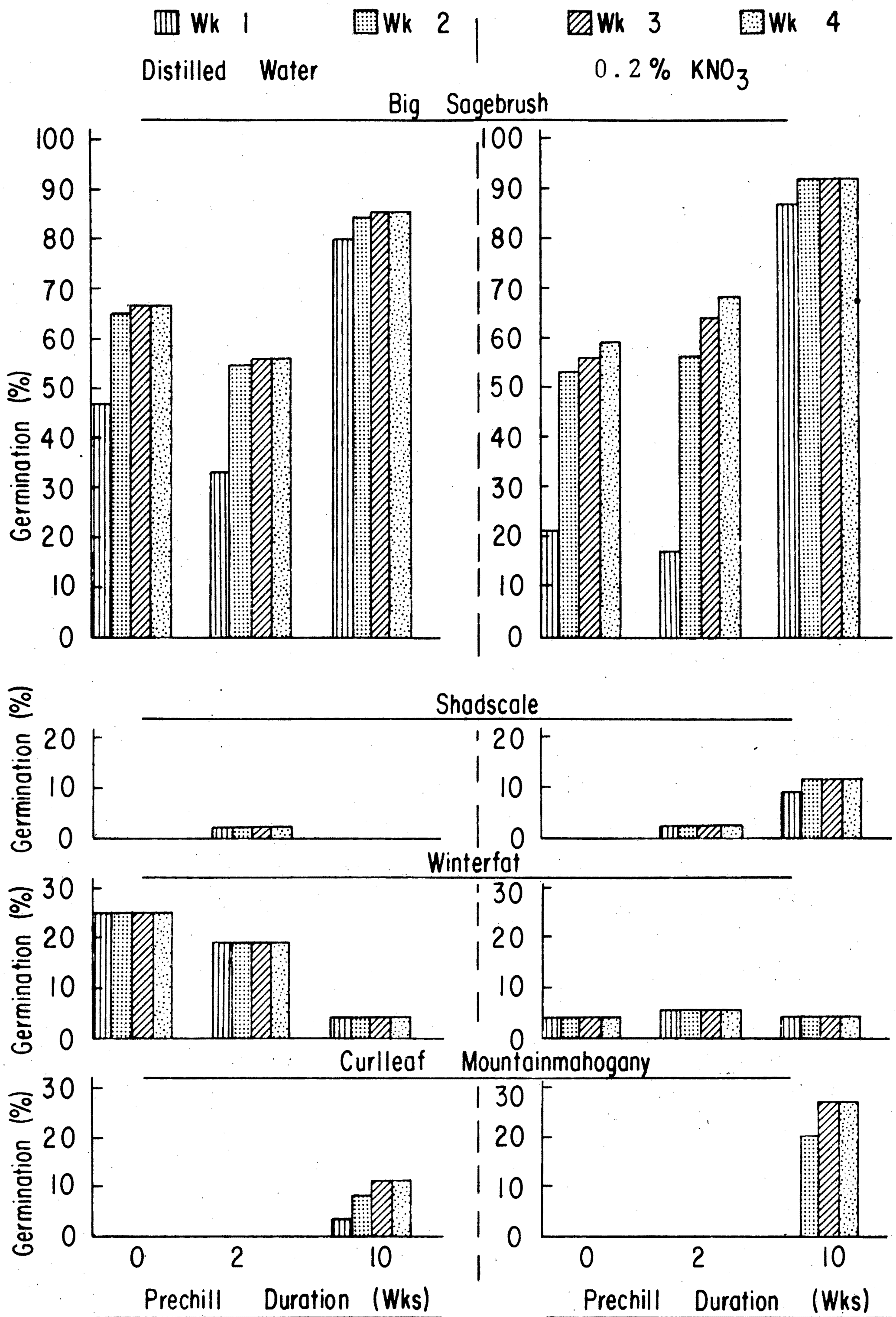


Figure 1. Weekly mean germination (%) of 4 browse species prechilled on substrate moistened with either distilled water or 0.2% KNO_3 solution for 0, 2, and 10 weeks prior to germination.

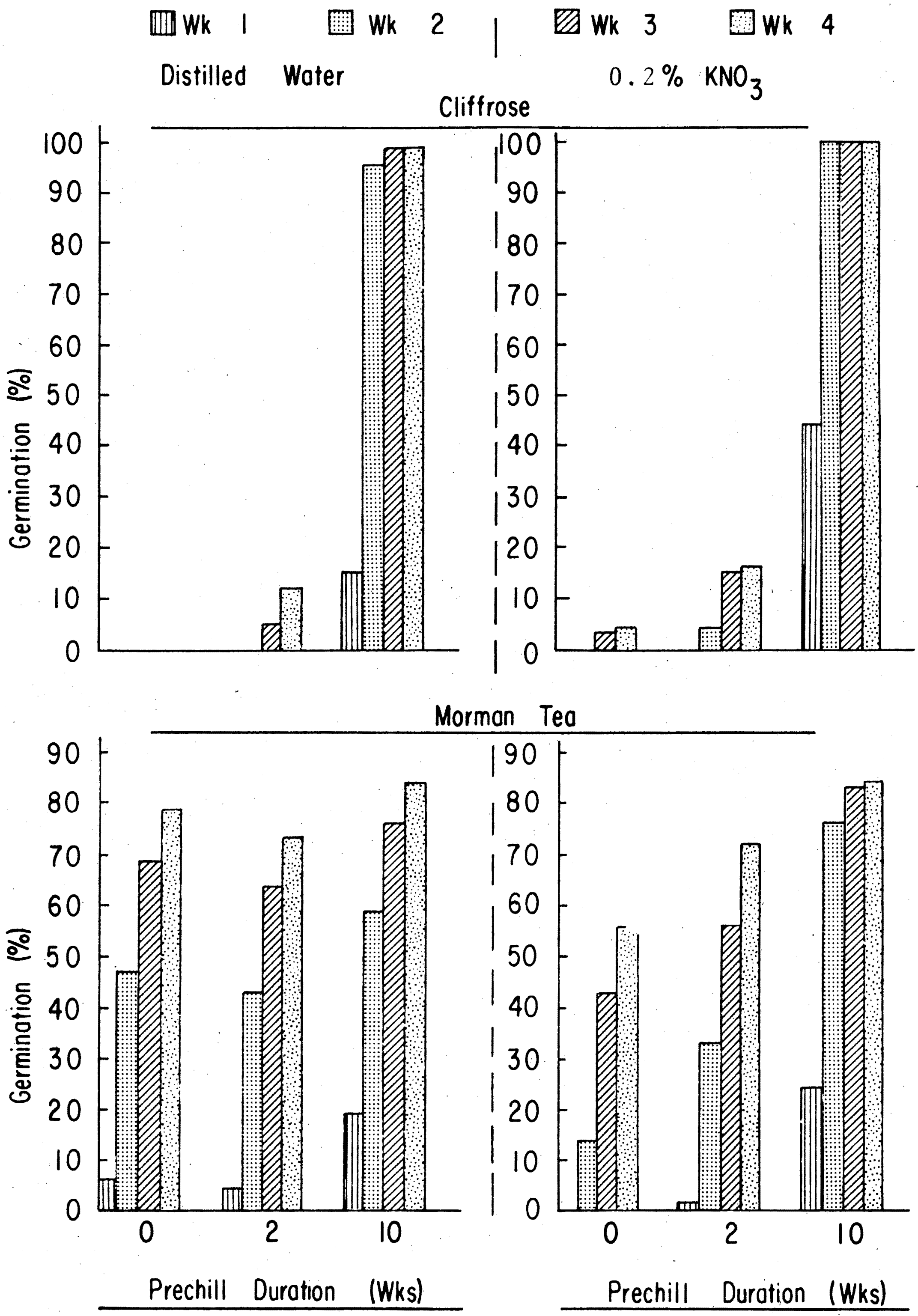


Figure 2. Weekly mean germination (%) of 2 browse species prechilled on substrate moistened with either distilled water or 0.2% KNO_3 solution for 0, 2, and 10 weeks prior to germination.

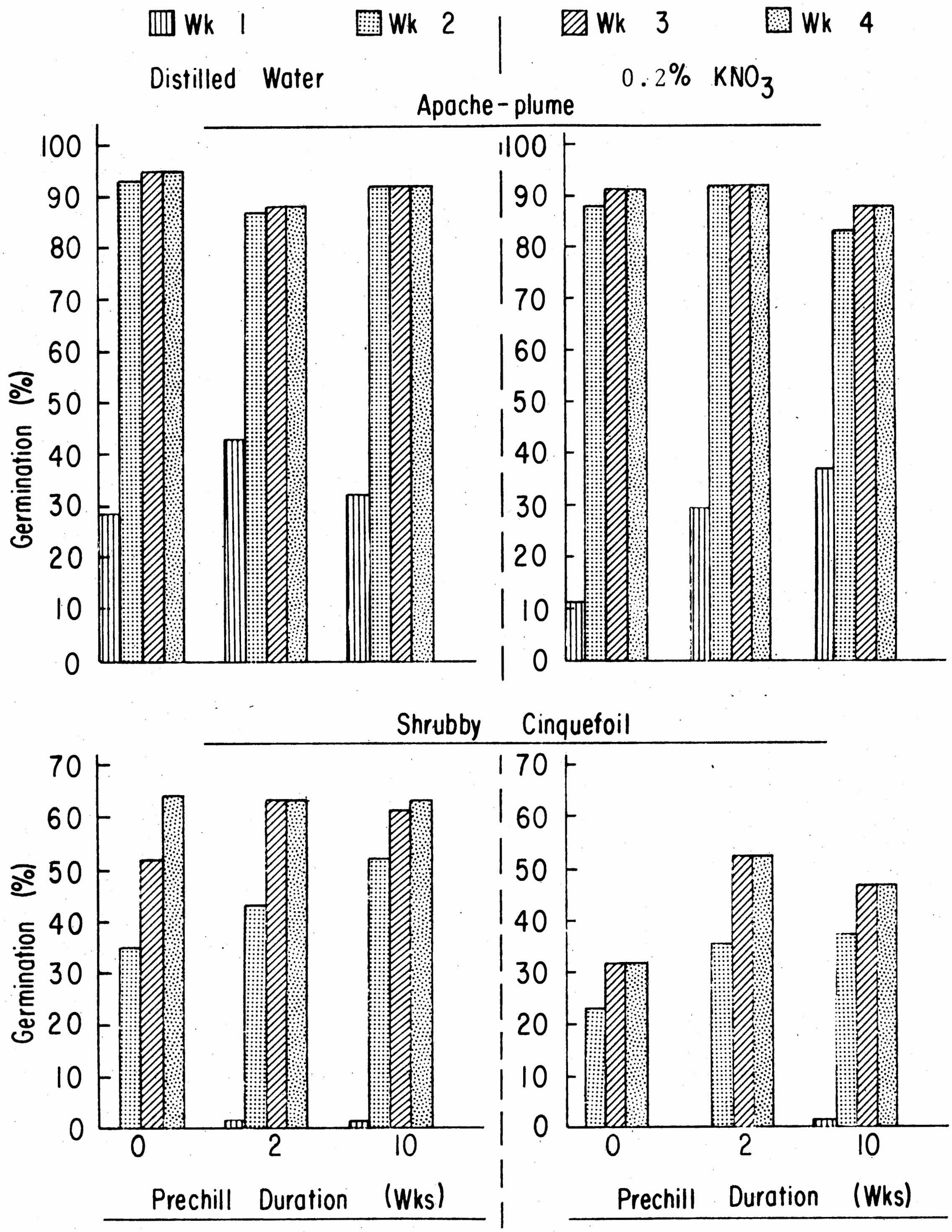


Figure 3. Weekly mean germination (%) of 2 browse species pre-chilled on substrate moistened with either distilled water or 0.2% KNO_3 solution for 0, 2, and 10 weeks prior to germination.

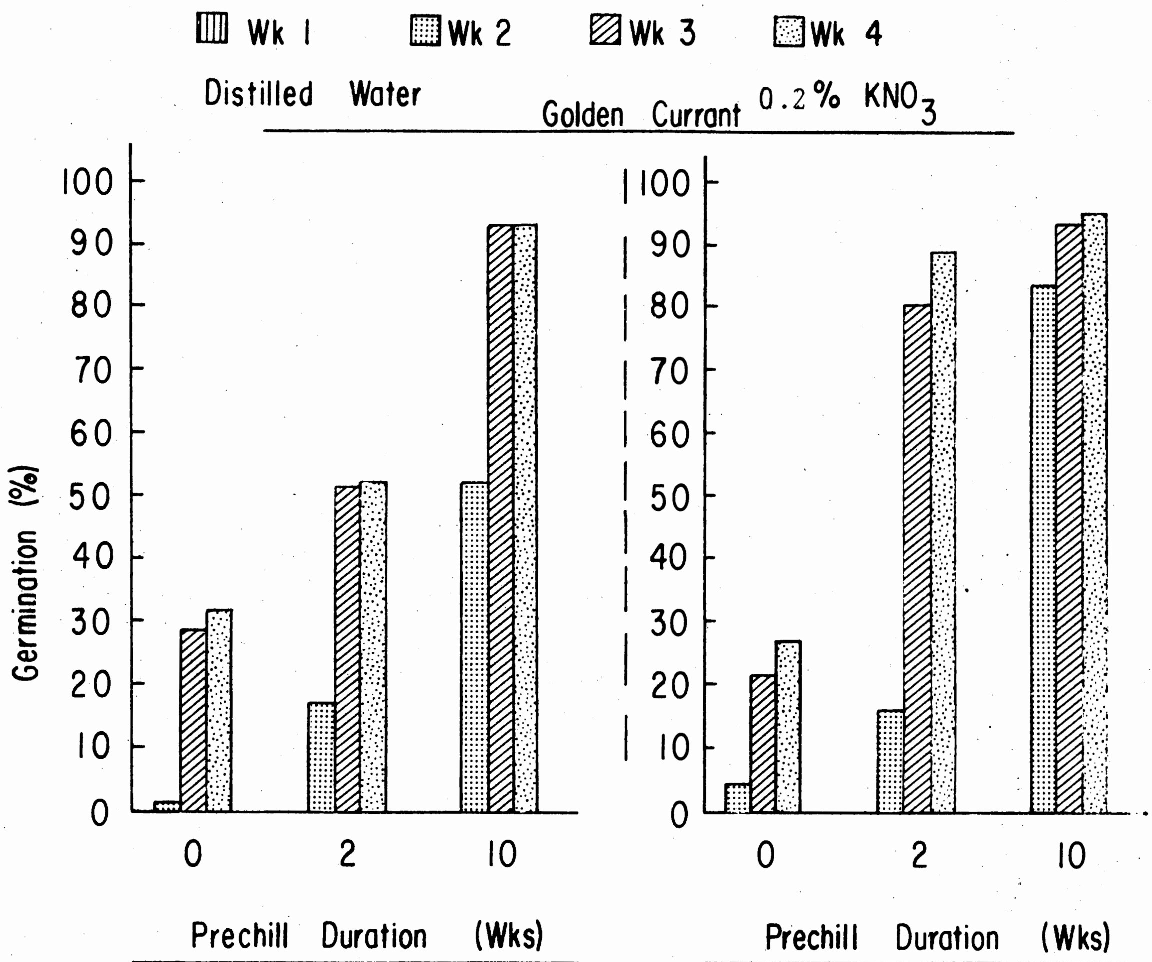
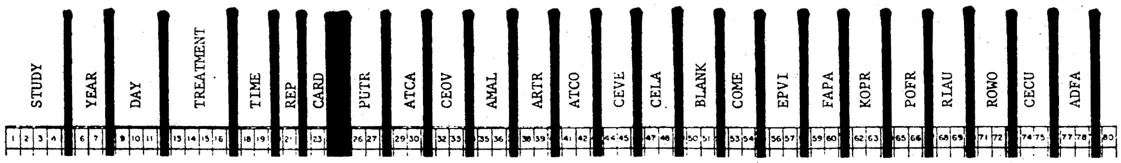


Figure 4. Weekly mean germination (%) of golden currant seeds prechilled on substrate moistened with either distilled water or 0.2% KNO_3 solution for 0, 2, and 10 weeks prior to germination.

APPENDIX G

THIOUREA DATA SHEET, INPUT, COMMENT, COMPUTER PROGRAM STATEMENTS, GERMINATION MEANS, AND WEEKLY GERMINATION FIGURES




```
TITLE 'STIDHAM SHRUB STUDY';
DATA THIOU; INPUT
   STUDY $ 1-4 YR 6-7 DAY 9-11 TRT $ 13-16 TIM 18-19 REP 21 CD 23
   PUTR 26-27 ATCA 29-30 CEOV 32-33 AMAL 35-36 ARTR 38-39 ATCO 41-42 CEVE 44-45
   CELA 47-48 COME 53-54 EPVI 56-57 FAPA 59-60 KOPR 62-63 POFR 65-66 RIAU 68-69
   ROWO 71-72 CECU 74-75 ADFA 77-78;
   PUTR=PUTR + 0; ATCA=ATCA + 0; CEOV=CEOV + 0; AMAL=AMAL + 0; ARTR=ARTR + 0;
   ATCO=ATCO + 0; CEVE=CEVE + 0; CELA=CELA + 0; COME=COME + 0; EPVI=EPVI + 0;
   FAPA=FAPA + 0; KOPR=KOPR + 0; POFR=POFR + 0; RIAU=RIAU + 0; ROWO=ROWO + 0;
   CECU=CECU + 0; ADFA=ADFA + 0;
```

```
COMMENT
   STUDY = THIOUREA TREATMENTS
      DAY AND YEAR = 12/10/76 THRU 12/30/76
      TREATMENTS = 3% SOLUTION OF THIOUREA FOR SOAKING SEEDS
      TIME = SOAKING TIME INTERVALS 0-MIN 20-MIN 40-MIN 60-MIN
      REPLICATION = 3 REPLICATIONS FOR ALL TREATMENTS AND TIMES
      CARD = DATA CARD NUMBER
      SPECIES
         PUTR = PURSHIA TRIDENTATA  ATCA = ATRIPLEX CANESCENS
         CEOV = CEANOTHUS OVATUS  AMAL = AMELANCHIER ALNIFOLIA
         ARTR = ARTEMISIA TRIDENTATA  ATCO = ATRIPLEX CONFERTIFOLIA
         CEVE = CEANOTHUS VELUTINUS  CELA = CERATOIDES LANATA
         COME = COWANIA MEXICANA STANSBURIANA  EPVI = EPHEDRA VIRIDUS
         FAPA = FALLUGIA PARADOXA  KOPR = KOCHIA PROSTRATA
         POFR = POTENTILLA FRUTICOSA  RIAU = RIBES AUREUM  ROWO = ROSA WOODSII
         CECU = CEANOTHUS CUNEATUS  ADFA = ADENOSTOMA FASCICULATUM;
```

```
PROC ANOVA DATA = THIOU; BY DAY;
  CLASSES REP TRT TIM; MEANS REP|TRT|TIM;
  MODEL PUTR ATCA CEOV AMAL ARTR ATCO = REP TRT|TIM;
     POOL 'TI' RESIDUAL/TIM;
     POOL 'TR' RESIDUAL/TRT;
     POOL 'TT' RESIDUAL/TIM*TRT;
     TEST TIM|TRT BY 'TT';
```

DATA SET THIOU

CLASSES	VALUES
REP	1 2 3
TRT	THIO
TIM	0 20 40 60

Table 1. Mean germination of 3 reps. for 4 browse species at 7, 14, 21, and 28 days germination. Species were soaked in a 0.3% thiourea solution for 0, 20, 40, and 60 minutes.

	Germination Days							
	7	14			21		28	
Species	Shrubby Cinquefoil	Jersey Tea	Cliffrose	Shrubby Cinquefoil	Cliffrose	Golden Currant	Jersey Tea	Golden Currant
Time (Minutes)								
0	--[1] a[2]	8.66 b	0.33 a	7.66 b	7.66 bc	0.66 a	8.66 b	0.66 a
20	0.66 b	2.00 a	-- a	4.00 ab	3.00 ab	1.33 a	6.33 ab	3.00 ab
40	-- a	1.33 a	-- a	4.00 ab	0.66 a	6.66 c	4.33 a	7.33 c
60	-- a	4.00 ab	2.33 b	2.33 a	9.66 c	3.00 b	8.00 ab	4.00 b
LSD $_{.05}$ Time	.58	5.81	1.45	5.24	6.52	1.60	4.10	2.42

[1]No germination.

[2]Means in the same column followed by a similar letter are not significantly different at the .05 level of probability.

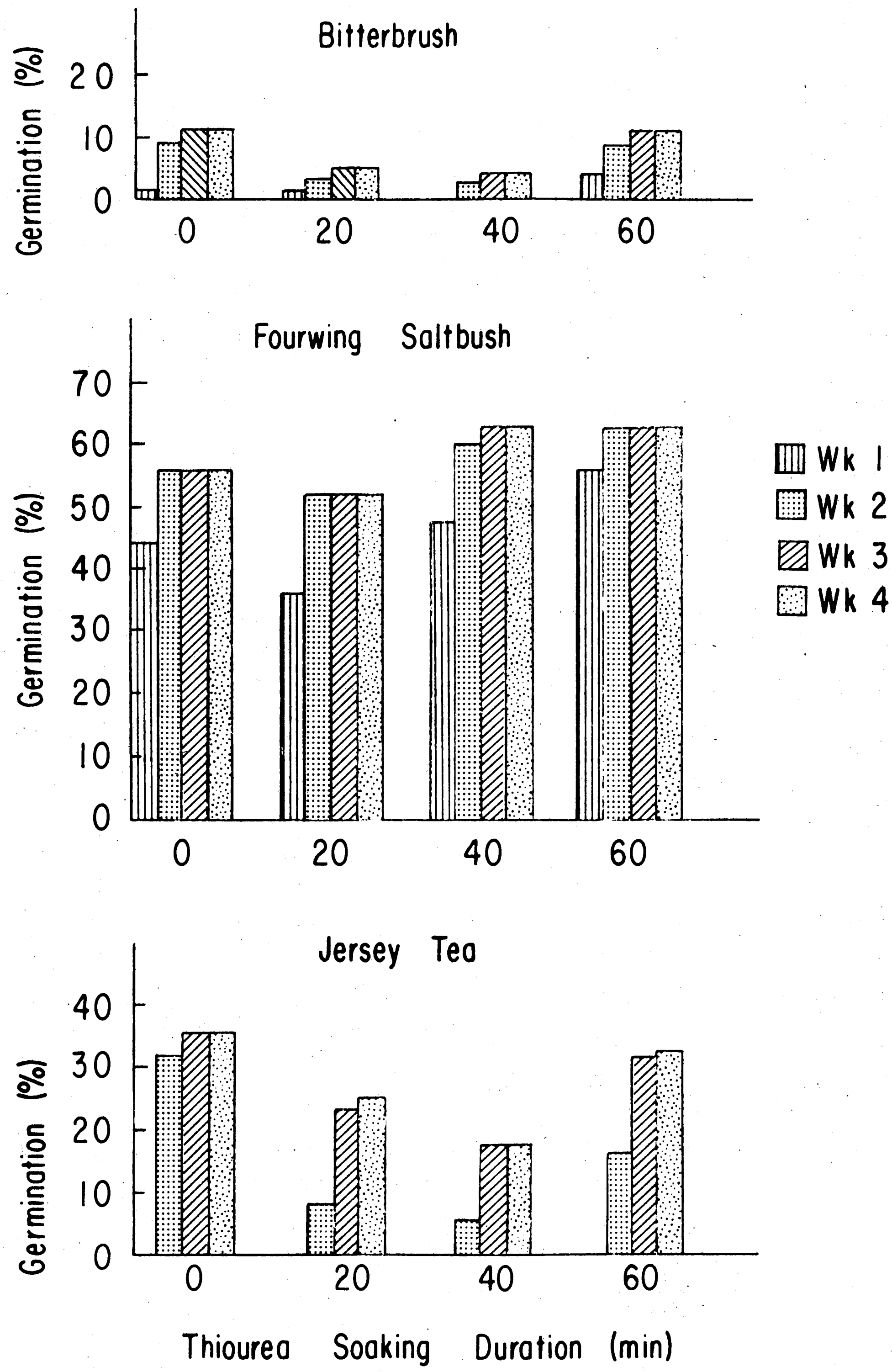


Figure 1. Weekly mean germination (%) of 3 browse species soaked in a 0.3% thiourea solution for 0, 20, 40, and 60 minutes prior to germination.

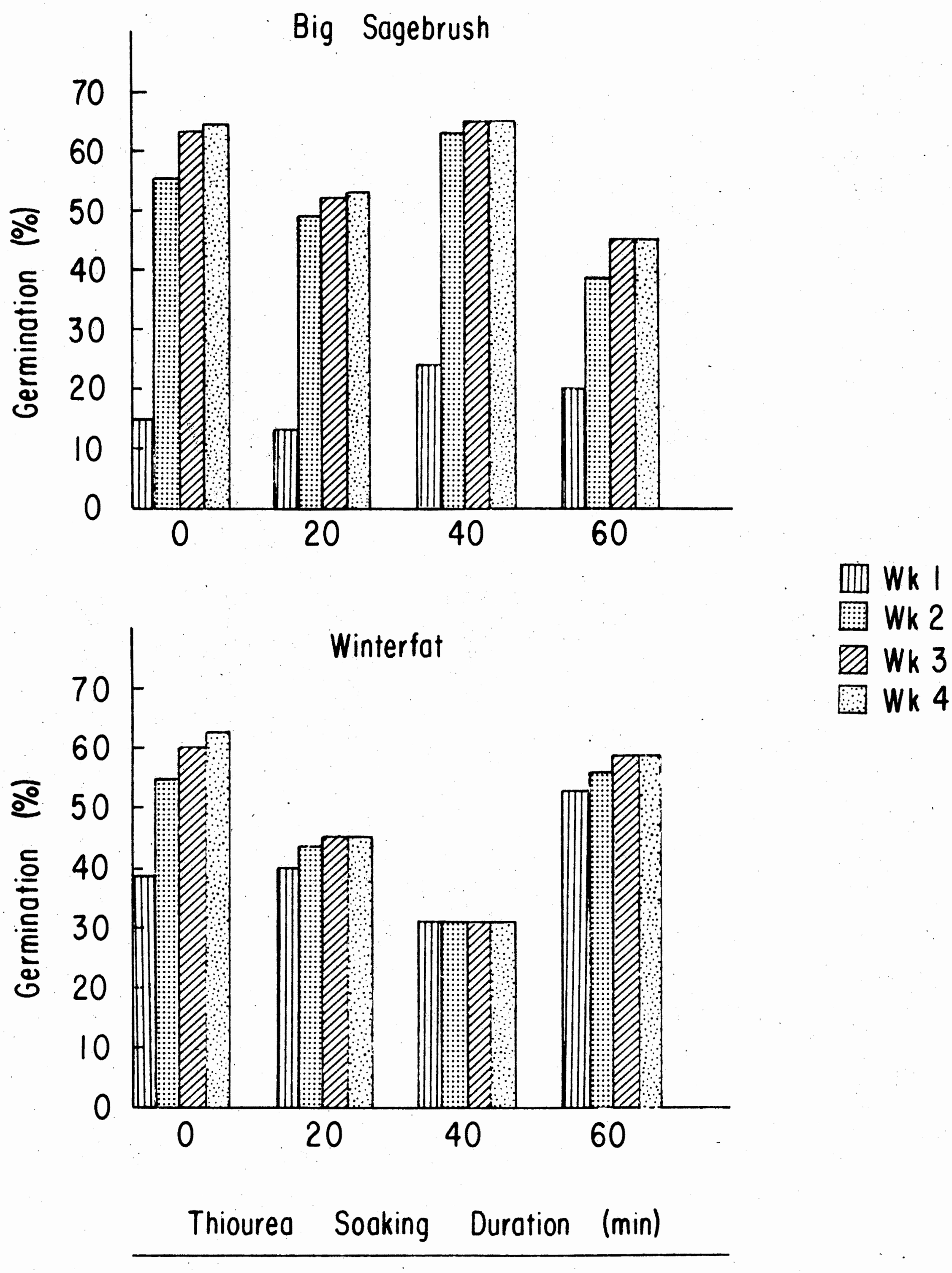


Figure 2. Weekly mean germination (%) of 2 browse species soaked in a 0.3% thiourea solution for 0, 20, 40, and 60 minutes prior to germination.

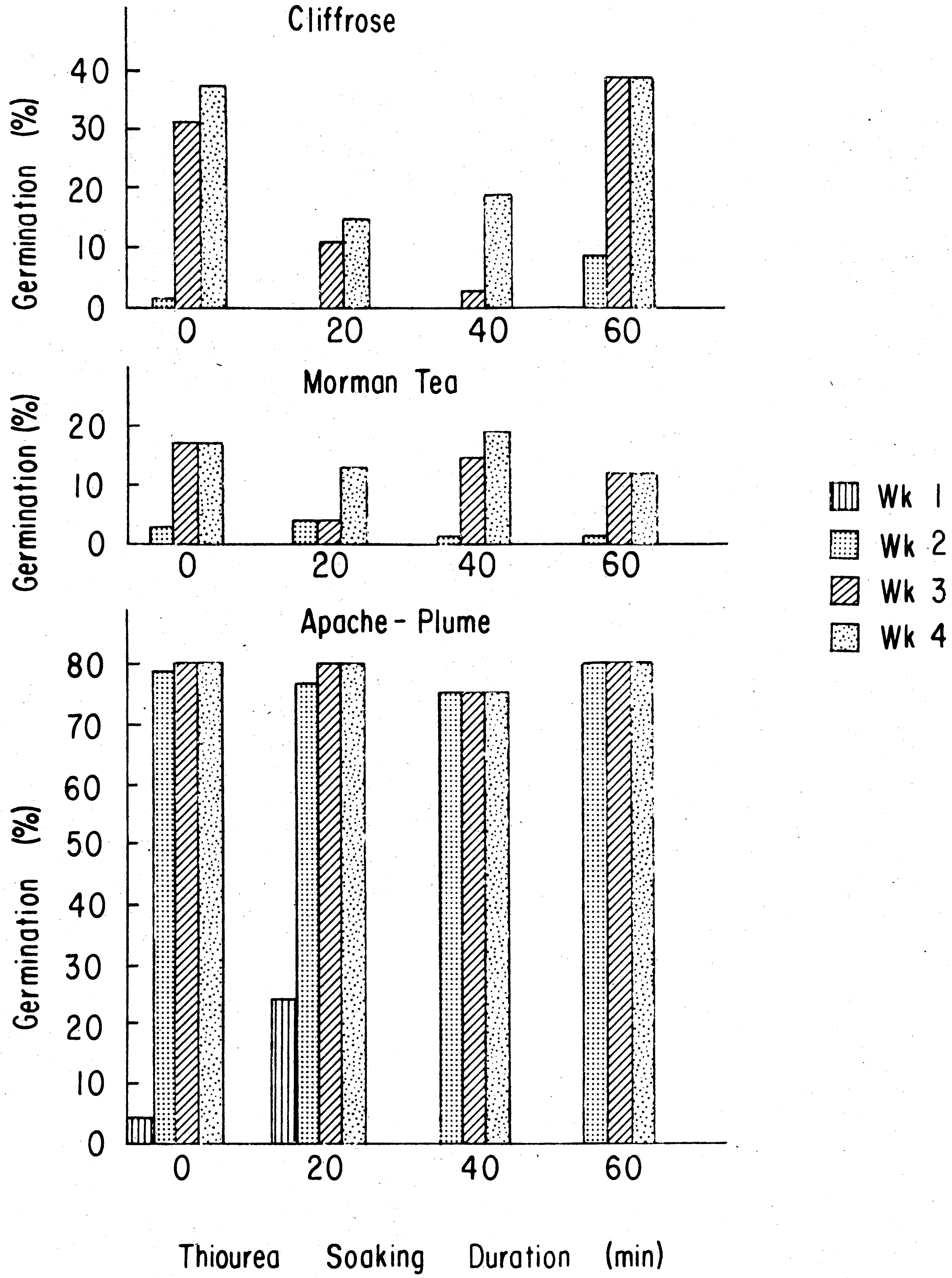


Figure 3. Weekly mean germination (%) of 3 browse species soaked in a 0.3% thiourea solution for 0, 20, 40, and 60 minutes prior to germination.

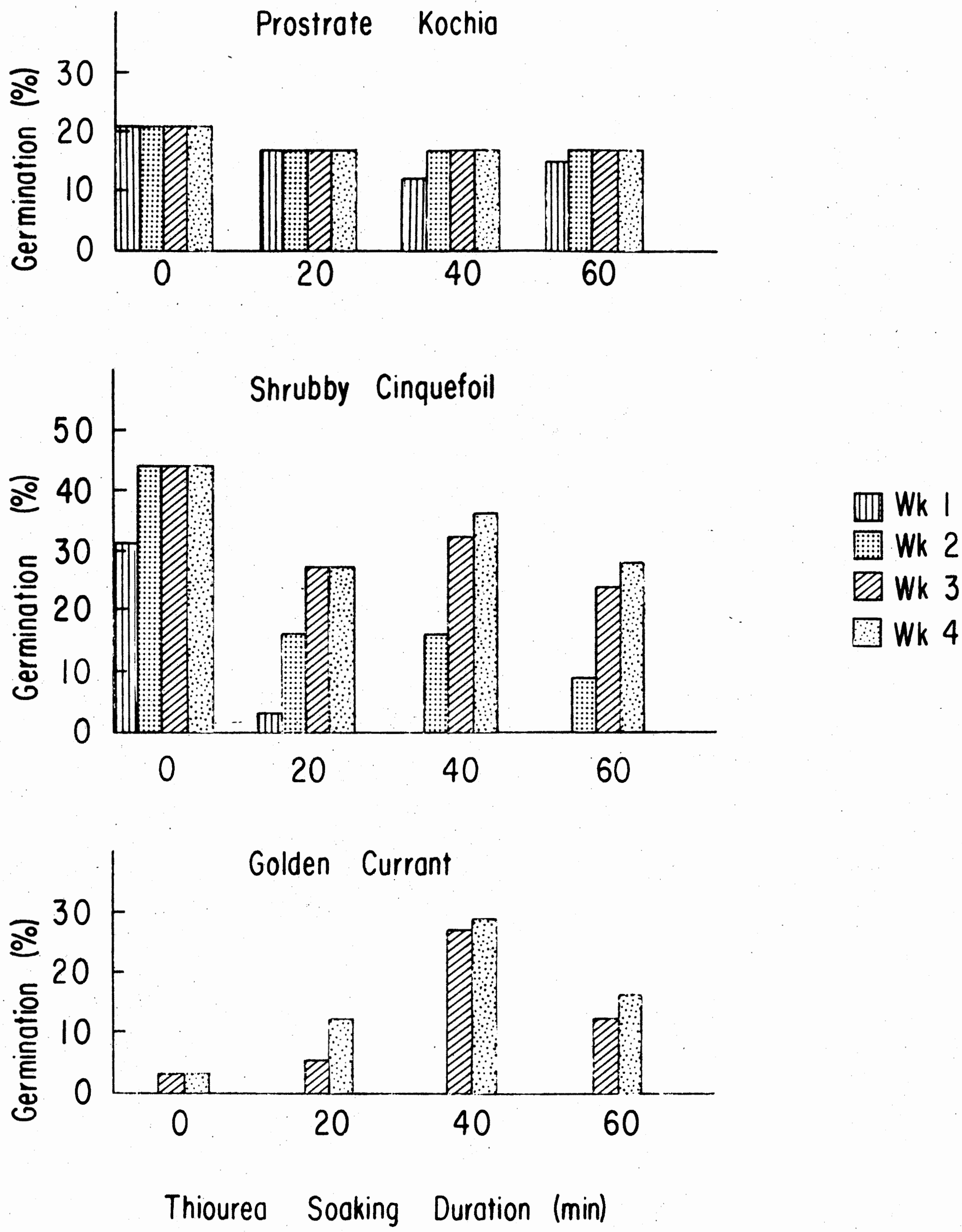


Figure 4. Weekly mean germination (%) of 3 browse species soaked in a 0.3% thiourea solution for 0, 20, 40, and 60 minutes prior to germination.

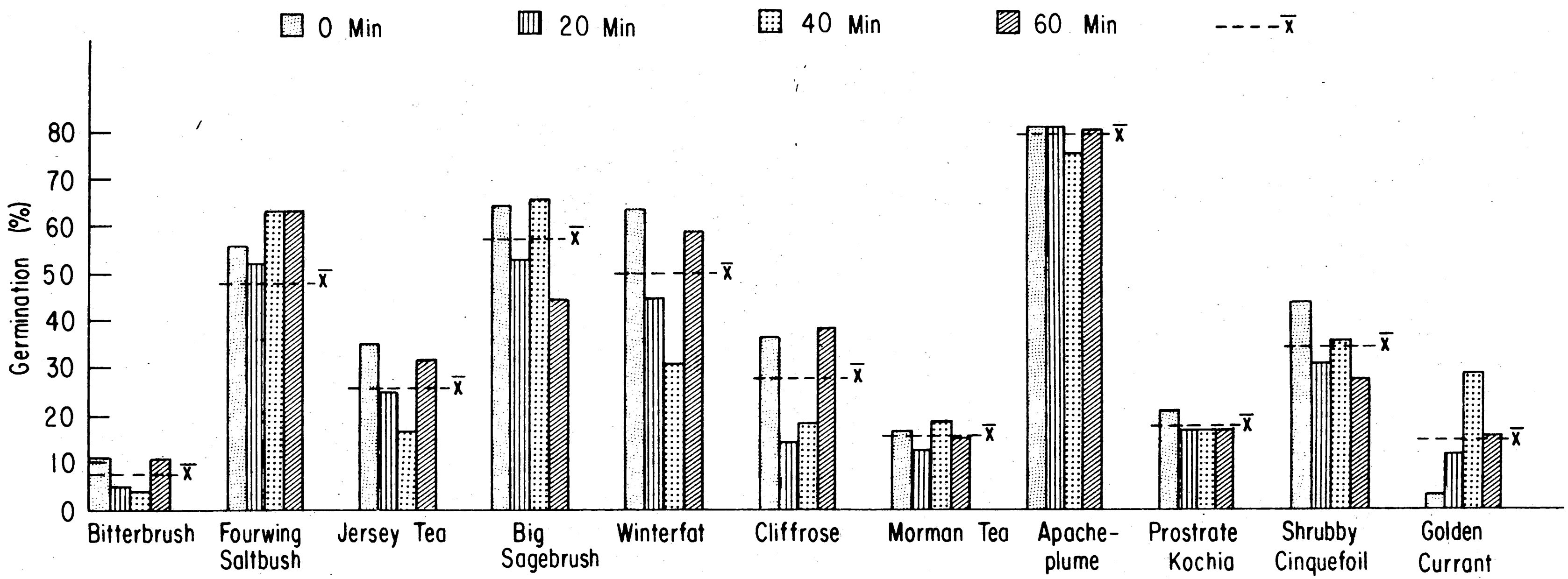


Figure 5. Mean germination (%) effects on seeds of 11 browse species soaked in a 0.3% thiourea solution for 0, 20, 40, and 60 minutes.

APPENDIX H

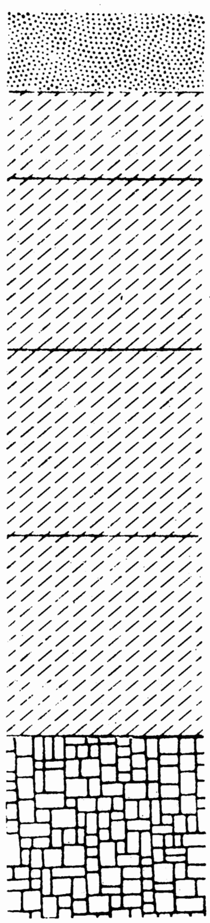
SOIL PROFILE DESCRIPTIONS

GRAINOLA SOIL PROFILE

Fine, mixed, thermic Vertic Haplustalf

Shallow Prairie Range Site

Profile was taken at Lake Carl Blackwell, 390 m W, 27 m S of NE Corner of Sec. 14; T19N; R1W. Payne County.



AP--0-10 cm -- Dark reddish brown (SYR3/4) silt loam; weak fine granular structure.

B1--10-23 cm -- Reddish brown (2.5YR4/4) silt loam; weak medium subangular blocky structure; firm; slightly acid; shiny ped surfaces; gradual wavy boundary.

B21t--23-46 cm -- Reddish brown (2.5YR4/4) silty clay, moderate coarse blocky breaking to find blocky structure; clay films on ped surfaces, very firm; neutral; few slickensides; gradual wavy boundary.

B22t--46-71 cm -- Red (2.5YR4/6) silty clay; weak coarse blocky structure; very firm; clay films on ped surfaces; few secondary carbonates; few fine Fe-Mn oxide bodies; few shale fragments; gradual wavey boundary.

B3t--71--96 cm -- Yellowish red (5YR5/6) silty clay loam; weak coarse blocky structure; firm; secondary carbonates; shiny ped surfaces; few Fe-Mn oxide bodies; few gypsum crystals; moderately alkaline; clear wavy boundary.

Cr--96-120 cm -- Bedded shale, siltstone and sandstone that varies from gray to red in color; moderately alkaline.

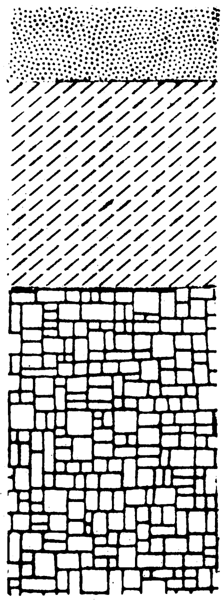
The Ap or A1 horizon is dark reddish brown, reddish brown or dark brown in hues 5YR or 7.5YR; reaction ranges from medium acid through moderately alkaline. The B2t is reddish brown, dark reddish brown or red in hues 2.5YR or 5YR; reaction is neutral through moderately alkaline. The B3t horizon, where present, is reddish brown, red or yellowish red in hues 2.5YR or 5YR; reaction is mildly or moderately alkaline.

LUCIEN SOIL PROFILE

Loamy, mixed, thermic, shallow Udic Ustochrepts[1]

Shallow Prairie Range Site

Profile was taken at Lake Carl Blackwell, 340 m W, 76 m S of the NE corner of the SE 1/4 of Sec. 4; T19N; R1W. Payne County



Ap--0-10 cm-- Dark Brown (10YR4/3) loam; weak fine granular structure; friable; neutral; clear smooth boundary.

B2--10-38 cm-- Reddish brown (5YR4/4) heavy loam; moderate fine subangular blocky structure; friable; thin clay films on ped surfaces; few soft sandstone fragments; slightly acid; gradual wavy boundary.

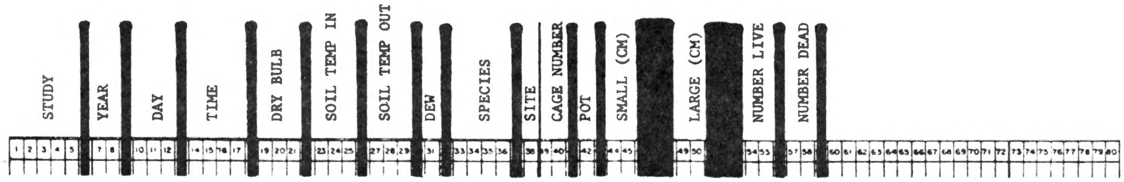
Cr--38--80 cm-- Beeded paralithic sandstone; moderately alkaline.

The A1 or Ap horizon is dark reddish brown or dark brown in hues 5YR through 10YR; reaction is neutral through medium acid. The B2 horizon is brown, reddish brown or yellowish red in hues 7.5YR, 5YR or 2.5YR; reaction is medium or slightly acid. The Cr horizon is bedded paralithic sandstone with seams of siltstone: colors are shades of red, brown or gray.

1/ Lucien soils are normally classified Udic Haplustolls, Mollisols.

APPENDIX I

APRIL SEPTEMBER DATA SHEET, INPUT, COMMENT, AND COMPUTER PROGRAM STATEMENTS FOR DETERMINING SUMMER PLANT GROWTH




```
TITLE 'STIDHAM SHRUB STUDY';
DATA APRHT; INPUT
  STUDY $ 1-5 YR 7-8 DAY 10-12 TIME 14-17 DRAT 19-21 SLTMPIN 23-25 SLTMPOT 27-29
    DEW 31 SPECIES $ 33-36 SITE 38 CAGE 39-40 POT $ 42 SML 44-45 LRG 49-50
    LIVE 54-55 DEAD 57-58;
    SML=SML+0; LRG=LRG+0; ALIVE=LIVE; ADEAD=DEAD; AXHT=(LRG+SML)/2;


COMMENT
  STUDY = APRIL HEIGHTS
    DAY AND YEAR = 4/1/77
    TIME = TIME OF DAY SAMPLING OCCURRED
    DRY BULB = DRY THERMOMETER READING ON SLING PSYCHROMETER
    SOIL TEMPERATURE IN = SOIL TEMPERATURE IN THE CAGE
    SOIL TEMPERATURE OUT = SOIL TEMPERATURE OUT SIDE OF THE CAGE
    DEW = WETTNESS OF VEGETATION 1-DRY 2-DAMP 3-WET
    SPECIES
      PUTR = PURSHIA TRIDENTATA  ATCA = ATRIPLEX CANESCENS
      CEOV = CEANOTHUS OVATUS  ARTR = ARTEMISIA TRIDENTATA
      ATCO = ATRIPLEX CONTERTIFOLIA  CEVE = CEANOTHUS VELUTINUS
      CELA = CERATOIDES LANATA  CELE = CERCOPARPUS LEDIFOLIUS
      COME = COWANIA MEXICANA STANSBURIANA  EPVI = EPHEDRA VIRIDUS
      POFR = POTENTILLA FRUTICOSA  RIAU = RIBES AUREUM
      FAPA = FALLUGIA PARADOXA  CECU = CEANOTHUS CUNEATUS
    SITE = SOIL TYPE 9-LUCIEN 0-GRAINOLA
    CAGE NUMBER =  CAGE ID EVEN NUMBERS=CAGED PLANTS ODD NUMBERS=GRAZED PLANTS
    POT = IDENTIFICATION OF DIFFERENT POTS OF EACH SPECIES  POT=REP/SP
    SMALL  = SMALLEST PLANT IN A POT (CM)
    LARGE = LARGEST PLANT IN A POT (CM)
    LIVE PLANTS = NUMBER OF LIVE PLANTS IN EACH POT
    DEAD PLANTS = NUMBER OF DEAD PLANTS IN EACH POT;



DATA SEPHT; INPUT
  STUDY $ 1-5 YR 7-8 DAY 10-12 TIME 14-17 DRAT 19-21 SLTMPIN 23-25 SLTMPOT 27-29
    DEW 31 SPECIES $ 33-36 SITE 38 CAGE 39-40 POT $ 42 SML 44-45 LRG 49-50
    LIVE 54-55 DEAD 57-58;
    SML=SML+0; LRG=LRG+0; SLIVE=LIVE; SDEAD=DEAD; SXHT=(LRG+SML)/2;


COMMENT
  STUDY = SEPTEMBER HEIGHTS
    DAY AND YEAR  9/1/77
    TIME = TIME OF DAY SAMPLING OCCURRED
    DRY BULB = DRY THERMOMETER READING ON SLING PSYCHROMETER
    SOIL TEMPERATURE IN = SOIL TEMPERATURE IN THE CAGE
    SOIL TEMPERATURE OUT = SOIL TEMPERATURE OUT SIDE OF THE CAGE
    DEW = WETTNESS OF VEGETATION 1-DRY 2-DAMP 3-WET
    SPECIES
      PUTR = PURSHIA TRIDENTATA  ATCA = ATRIPLEX CANESCENS
      CEOV = CEANOTHUS OVATUS  ARTR = ARTEMISIA TRIDENTATA
      ATCO = ATRIPLEX CONTERTIFOLIA  CEVE = CEANOTHUS VELUTINUS
      CELA = CERATOIDES LANATA  CELE = CERCORARPUS LEDIFOLIUS
      COME = COWANIA MEXICANA STANSBURIANA  EPVI = EPHEDRA VIRIDUS
      POFR = POTENTILLA FRUTICOSA  RIAU = RIBES AUREUM
      FAPA = FALLUGIA PARADOXA  CECU = CEANOTHUS CUNEATUS
      CEMO = CERCOCARPUS MONTANUS  ARFR = ARTEMISIA FRIGIDA
    SITE = SOIL TYPE 9-LUCIEN 0-GRAINOLA
    CAGE NUMBER =  CAGE ID EVEN NUMBERS=CAGED PLANTS ODD NUMBERS=GRAZED PLANTS
    POT = IDENTIFICATION OF DIFFERENT POTS OF EACH SPECIES  POT=REP/SP
    SMALL  = SMALLEST PLANT IN A POT (CM)
    LARGE = LARGEST PLANT IN A POT (CM)
    LIVE PLANTS = NUMBER OF LIVE PLANTS IN EACH POT
    DEAD PLANTS = NUMBER OF DEAD PLANTS IN EACH POT;
```

```
PROC SORT OUT=APRHTS DATA=APRHT; BY SITE SPECIES POT CAGE;


PROC SORT OUT=SEPHTS DATA=SEPHT; BY SITE SPECIES POT CAGE;


DATA ASPHTS; MERGE APRHTS SEPHTS; BY SITE SPECIES POT CAGE;
 SAHT=SXHT-AXHT;  SDEAD=ALIVE-SLIVE;


PROC ANOVA DATA=ASPHTS; CLASSES SITE SPECIES; MEANS SITE|SPECIES;
MODEL ALIVE AXHT SLIVE SXHT SAHT SDEAD=SITE|SPECIES;
  POOL 'SSP' SITE*SPECIES/SITE;
  TEST SITE BY 'SSP';
  TEST SPECIES BY 'SSP';
```

DATA SET ASPHTS

CLASSES	VALUES
SITE	0 9
SPECIES	ARTR ATCA CELA CELE CEOV COME EPVI FAPA PUTR RIAU

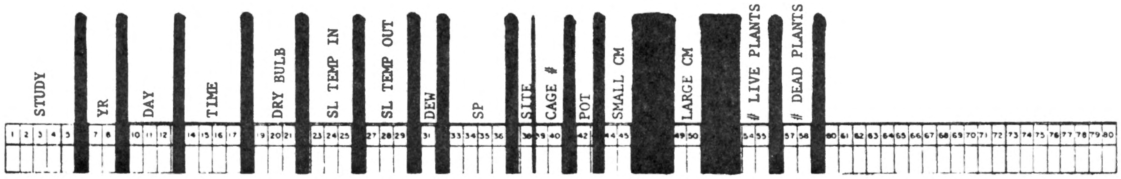
```
PROC MEANS DATA=ASPHTS;
VAR ALIVE AXHT SLIVE SXHT SAHT SDEAD;
BY SITE SPECIES;
```

APPENDIX J

SEPTEMBER NOVEMBER DATA SHEETS, INPUT, COMMENT, AND

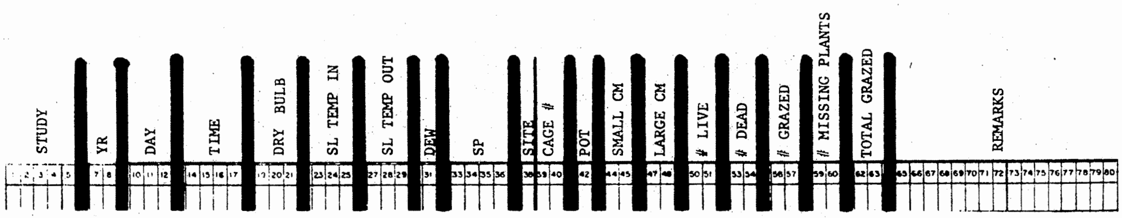
COMPUTER PROGRAM STATEMENTS FOR DETERMINING

FALL PLANT UTILIZATION




```
TITLE 'STIDHAM SHRUB STUDY';
DATA SEPHT; INPUT
  STUDY $ 1-5 YR 7-8 DAY 10-12 TIME 14-17 DRAT 19-21 SLTMPIN 23-25 SLTMPOT 27-29
    DEW 31 SPECIES $ 33-36 SITE 38 CAGE 39-40 POT $ 42 SML 44-45 LRG 49-50
    LIVE 54-55 DEAD 57-58;
    SML=SML+0; LRG=LRG+0; SLIVE=LIVE; SDEAD=DEAD; SXHT=(LRG+SML)/2;
```

```
COMMENT
  STUDY = SEPTEMBER HEIGHTS
    DAY AND YEAR  9/1/77
    TIME = TIME OF DAY SAMPLING OCCURRED
    DRY BULB = DRY THERMOMETER READING ON SLING PSYCHROMETER
    SOIL TEMPERATURE IN = SOIL TEMPERATURE IN THE CAGE
    SOIL TEMPERATURE OUT = SOIL TEMPERATURE OUT SIDE OF THE CAGE
    DEW = WETTNESS OF VEGETATION 1-DRY 2-DAMP 3-WET
    SPECIES
      PUTR = PURSHIA TRIDENTATA  ATCA = ATRIPLEX CANESCENS
      CEOV = CEANOTHUS OVATUS  ARTR = ARTEMISIA TRIDENTATA
      ATCO = ATRIPLEX CONTERTIFOLIA  CEVE = CEANOTHUS VELUTINUS
      CELA = CERATOIDES LANATA  CELE = CERCORARPUS LEDIFOLIUS
      COME = COWANIA MEXICANA STANSBURIANA  EPVI = EPHEDRA VIRIDUS
      POFR = POTENTILLA FRUTICOSA  RIAU = RIBES AUREUM
      FAPA = FALLUGIA PARADOXA  CECU = CEANOTHUS CUNEATUS
      CEMO = CERCOCARPUS MONTANUS  ARFR = ARTEMISIA FRIGIDA
    SITE = SOIL TYPE 9-LUCIEN 0-GRAINOLA
    CAGE NUMBER =  CAGE ID EVEN NUMBERS=CAGED PLANTS ODD NUMBERS=GRAZED PLANTS
    POT = IDENTIFICATION OF DIFFERENT POTS OF EACH SPECIES  POT=REP/SP
    SMALL  = SMALLEST PLANT IN A POT (CM)
    LARGE = LARGEST PLANT IN A POT (CM)
    LIVE PLANTS = NUMBER OF LIVE PLANTS IN EACH POT
    DEAD PLANTS = NUMBER OF DEAD PLANTS IN EACH POT;
```




```
DATA NOVGZ; INPUT
  STUDY $ 1-5 YR 7-8 DAY 10-12 TIME 14-17 DRAT 19-21 SLTMPIN 23-25 SLTMPOT 27-29
    DEW 31 SPECIES $ 33-36 SITE 38 CAGE 39-40 POT $ 42 SML 44-45 LRG 47-48
    LIVE 50-51 DEAD 53-54 GRAZED 56-57 MISPLNTS 59-60 TOTGRAZD 62-63
    REMARKS $ 65-80;
    SML=SML+0; LRG=LRG+0; NLIVE=LIVE; NXHT=(LRG+SML)/2;
```

```
COMMENT
  STUDY = NOVEMBER GRAZED PLANT HEIGHTS
    DAY AND YEAR = 11/20/77
    TIME = TIME OF DAY SAMPLING OCCURRED
    DRY BULB = DRY THERMOMETER READING ON SLING PSYCHROMETER
    SOIL TEMPERATURE IN = SOIL TEMPERATURE IN THE CAGE
    SOIL TEMPERATURE OUT = SOIL TEMPERATURE OUT SIDE OF THE CAGE
    DEW = WETTNESS OF VEGETATION 1-DRY 2-DAMP 3-WET
    SPECIES
      PUTR = PURSHIA TRIDENTATA  ATCA = ATRIPLEX CANESCENS
      CEOV = CEANOTHUS OVATUS  ARTR = ARTEMISIA TRIDENTATA
      COME = COWANIA MEXICANA STANSBURIANA  EPVI = EPHEDRA VIRIDUS
      FAPA = FALLUGIA PARADOXA  CECU = CEANOTHUS CUNEATUS
      POFR = POTENTILLA FRUTICOSA  RIAU = RIBES AUREUM
      CEMO = CERCOCARPUS MONTANUS  ARFR = ARTEMISIA FRIGIDA
    SITE = SOIL TYPE 9-LUCIEN 0-GRAINOLA
    CAGE NUMBER =  CAGE ID EVEN NUMBERS=CAGED PLANTS ODD NUMBERS=GRAZED PLANTS
    POT = IDENTIFICATION OF DIFFERENT POTS OF EACH SPECIES  POT=REP/SP
    SMALL  = SMALLEST PLANT IN A POT (CM)
    LARGE = LARGEST PLANT IN A POT (CM)
    LIVE PLANTS = NUMBER OF LIVE PLANTS IN EACH POT
    DEAD PLANTS = NUMBER OF DEAD PLANTS IN EACH POT
    GRAZED = ACTUAL VISIBLE GRAZED PLANTS
    MISSING PLANTS = SEPGZ LIVE AND DEAD-NOVGZ LIVE AND DEAD
      MISSING PLANTS ARE CONSIDERED GRAZED
    TOTAL GRAZED PLANTS = MISSING PLANTS PLUS GRAZED PLANTS
    REMARKS = ADDITIONAL COMMENTS OR OBSERVATIONS NOTED WHEN SAMPLING;
```

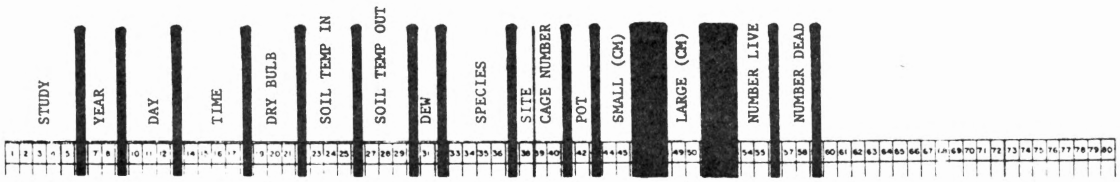
```
PROC SORT OUT=SEPHTS DATA=SEPHT; BY SITE SPECIES POT CAGE;


PROC SORT OUT=NOVGZS DATA=NOVGZ; BY SITE SPECIES POT CAGE;


DATA SNOVHTS; MERGE SEPHTS NOVGZS; BY SITE SPECIES POT CAGE;
SNOHT=SXHT-NXHT; PCUTIL=DIV(SNOHT,SXHT);


PROC PRINT DATA=SNOVHTS; BY SITE; ID SPECIES POT CAGE;
   VAR GRAZED PCUTIL SNOHT MISPLNTS TOTGRAZD;


PROC ANOVA DATA=SNOVHTS; CLASSES SITE SPECIES; MEANS SITE|SPECIES;
MODEL GRAZED PCUTIL SNOHT MISPLNTS TOTGRAZD;
  POOL 'SSP' SITE*SPECIES/SITE;
  TEST SITE BY 'SSP';
  TEST SPECIES BY 'SSP';
```

```
DATA SET SNOVHTS

CLASSES       VALUES

SITE          0 9

SPECIES       ARFR ARTR ATCA CEMO CEOV COME EPVI FAPA PUTR RIAU
```

```
PROC MEANS DATA=SNOVHTS;
   VAR GRAZED PCUTIL SNOHT MISPLNTS TOTGRAZD;
   BY SITE SPECIES;
```

APPENDIX K

APRIL-NOVEMBER DATA SHEETS, INPUT, COMMENT, AND
COMPUTER PROGRAM STATEMENTS FOR DETERMINING
GROWTH, SPECIES SURVIVAL, AND
UTILIZATION MEANS




```
TITLE 'STIDHAM SHRUB STUDY';
DATA APRHT; INPUT
  STUDY $ 1-5 YR 7-8 DAY 10-12 TIME 14-17 DRAT 19-21 SLTMPIN 23-25 SLTMPOT 27-29
    DEW 31 SPECIES $ 33-36 SITE 38 CAGE 39-40 POT $ 42 SML 44-45 LRG 49-50
    LIVE 54-55 DEAD 57-58;
    SML=SML+0; LRG=LRG+0; ALIVE=LIVE; ADEAD=DEAD; AXHT=(LRG+SML)/2;


COMMENT
  STUDY = APRIL HEIGHTS
    DAY AND YEAR = 4/1/77
    TIME = TIME OF DAY SAMPLING OCCURRED
    DRY BULB = DRY THERMOMETER READING ON SLING PSYCHROMETER
    SOIL TEMPERATURE IN = SOIL TEMPERATURE IN THE CAGE
    SOIL TEMPERATURE OUT = SOIL TEMPERATURE OUT SIDE OF THE CAGE
    DEW = WETTNESS OF VEGETATION 1-DRY 2-DAMP 3-WET
    SPECIES
      PUTR = PURSHIA TRIDENTATA  ATCA = ATRIPLEX CANESCENS
      CEOV = CEANOTHUS OVATUS  ARTR = ARTEMISIA TRIDENTATA
      ATCO = ATRIPLEX CONTERTIFOLIA  CEVE = CEANOTHUS VELUTINUS
      CELA = CERATOIDES LANATA  CELE = CERCOCARPUS LEDIFOLIUS
      COME = COWANIA MEXICANA STANSBURIANA  EPVI = EPHEDRA VIRIDUS
      POFR = POTENTILLA FRUTICOSA  RIAU = RIBES AUREUM
      FAPA = FALLUGIA PARADOXA  CECU = CEANOTHUS CUNEATUS
    SITE = SOIL TYPE 9-LUCIEN 0-GRAINOLA
    CAGE NUMBER =  CAGE ID EVEN NUMBERS=CAGED PLANTS ODD NUMBERS=GRAZED PLANTS
    POT = IDENTIFICATION OF DIFFERENT POTS OF EACH SPECIES  POT=REP/SP
    SMALL  = SMALLEST PLANT IN A POT (CM)
    LARGE = LARGEST PLANT IN A POT (CM)
    LIVE PLANTS = NUMBER OF LIVE PLANTS IN EACH POT
    DEAD PLANTS = NUMBER OF DEAD PLANTS IN EACH POT;



DATA NOVCG; INPUT
  STUDY $ 1-5 YR 7-8 DAY 10-12 TIME 14-17 DRAT 19-21 SLTMPIN 23-25 SLTMPOT 27-29
    DEW 31 SPECIES $ 33-36 SITE 38 CAGE 39-40 POT $ 42 SML 44-45 LRG 49-50
    LIVE 55-56 DEAD 59-60 REMARKS $ 62-80;
    SML=SML+0; LRG=LRG+0; NLIVE=LIVE; NXHT=(LRG+SML)/2;


COMMENT
  STUDY = NOVEMBER CAGED PLANT HEIGHTS
    DAY AND YEAR = 11/20/77
    DRY BULB = DRY THERMOMETER READING ON SLING PSYCHROMETER
    DEW = WETTNESS OF VEGETATION 1-DRY 2-DAMP 3-WET
    SPECIES
      PUTR = PURSHIA TRIDENTATA  ATCA = ATRIPLEX CANESCENS
      CEOV = CEANOTHUS OVATUS  ARTR = ARTEMISIA TRIDENTATA
      ATCO = ATRIPLEX CONTERTIFOLIA  CEVE = CEANOTHUS VELUTINUS
      CELA = CERATOIDES LANATA  CELE = CERCOCARPUS LEDIFOLIUS
      COME = COWANIA MEXICANA STANSBURIANA  EPVI = EPHEDRA VIRIDUS
      POFR = POTENTILLA FRUTICOSA  RIAU = RIBES AUREUM
      CEMO = CERCOCARPUS MONTANUS  ARFR = ARTEMISIA FRIGIDA
      FAPA = FALLUGIA PARADOXA
    SITE = SOIL TYPE 9-LUCIEN 0-GRAINOLA
    CAGE NUMBER =  CAGE ID EVEN NUMBERS=CAGED PLANTS ODD NUMBERS=GRAZED PLANTS
    POT = IDENTIFICATION OF DIFFERENT POTS OF EACH SPECIES  POT=REP/SP
    SMALL  = SMALLEST PLANT IN A POT (CM)
    LARGE = LARGEST PLANT IN A POT (CM)
    LIVE PLANTS = NUMBER OF LIVE PLANTS IN EACH POT
    DEAD PLANTS = NUMBER OF DEAD PLANTS IN EACH POT
    REMARKS = ADDITIONAL COMMENTS OR OBSERVATIONS NOTED WHEN SAMPLING;
```

STUDY	YEAR	DAY	TIME	DRY BULB	SOIL TEMP IN	SOIL TEMP OUT	DEW	SPECIES	SITE	CAGE NUMBER	POT	SMALL (CM)	LARGE (CM)	NUMBER LIVE	NUMBER DEAD	NUMBER GRAZED	MISSING PLANTS	TOTAL GRAZED	REMARKS
1 2 3 4 5	7 8	10 11 12	14 15 16 17	19 20 21	23 24 25	27 28 29	31	33 34 35 36	38	39 40	42	44 45	47 48	50 51	53 54	56 57	59 60	62 63	65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

```
DATA NOVGZ; INPUT
  STUDY $ 1-5 YR 7-8 DAY 10-12 TIME 14-17 DRAT 19-21 SLTMPIN 23-25 SLTMPOT 27-29
    DEW 31 SPECIES $ 33-36 SITE 38 CAGE 39-40 POT $ 42 SML 44-45 LRG 47-48
    LIVE 50-51 DEAD 53-54 GRAZED 56-57 MISPLNTS 59-60 TOTGRAZD 62-63
    REMARKS $ 65-80;
    SML=SML+0; LRG=LRG+0; NLIVE=LIVE; NXHT=(LRG+SML)/2;


COMMENT
  STUDY = NOVEMBER GRAZED PLANT HEIGHTS
    DAY AND YEAR = 11/20/77
    TIME = TIME OF DAY SAMPLING OCCURRED
    DRY BULB = DRY THERMOMETER READING ON SLING PSYCHROMETER
    SOIL TEMPERATURE IN = SOIL TEMPERATURE IN THE CAGE
    SOIL TEMPERATURE OUT = SOIL TEMPERATURE OUT SIDE OF THE CAGE
    DEW = WETTNESS OF VEGETATION 1-DRY 2-DAMP 3-WET
    SPECIES
      PUTR = PURSHIA TRIDENTATA  ATCA = ATRIPLEX CANESCENS
      CEOV = CEANOTHUS OVATUS  ARTR = ARTEMISIA TRIDENTATA
      COME = COWANIA MEXICANA STANSBURIANA  EPVI = EPHEDRA VIRIDUS
      FAPA = FALLUGIA PARADOXA  CECU = CEANOTHUS CUNEATUS
      POFR = POTENTILLA FRUTICOSA  RIAU = RIBES AUREUM
      CEMO = CERCOCARPUS MONTANUS  ARFR = ARTEMISIA FRIGIDA
    SITE = SOIL TYPE 9-LUCIEN 0-GRAINOLA
    CAGE NUMBER =  CAGE ID EVEN NUMBERS=CAGED PLANTS ODD NUMBERS=GRAZED PLANTS
    POT = IDENTIFICATION OF DIFFERENT POTS OF EACH SPECIES  POT=REP/SP
    SMALL  = SMALLEST PLANT IN A POT (CM)
    LARGE = LARGEST PLANT IN A POT (CM)
    LIVE PLANTS = NUMBER OF LIVE PLANTS IN EACH POT
    DEAD PLANTS = NUMBER OF DEAD PLANTS IN EACH POT
    GRAZED = ACTUAL VISIBLE GRAZED PLANTS
    MISSING PLANTS = SEPGZ LIVE AND DEAD-NOVGZ LIVE AND DEAD
      MISSING PLANTS ARE CONSIDERED GRAZED
    TOTAL GRAZED PLANTS = MISSING PLANTS PLUS GRAZED PLANTS
    REMARKS = ADDITIONAL COMMENTS OR OBSERVATIONS NOTED WHEN SAMPLING;



PROC SORT OUT=APRHTS DATA=APRHT; BY SITE SPECIES POT CAGE;


PROC SORT OUT=NOVCGS DATA=NOVCG; BY SITE SPECIES POT CAGE;


PROC SORT OUT=NOVGZS DATA=NOVGZ; BY SITE SPECIES POT CAGE;


DATA NOVHT; MERGE NOVCGS NOVGZS; BY  SITE SPECIES POT CAGE;
```

```
PROC SORT OUT=NOVHTS DATA=NOVHT; BY SITE SPECIES POT CAGE;

DATA ANOVHTS; MERGE APRHTS NOVHTS; BY SITE SPECIES POT CAGE;
  PCSURV=DIV(NLIVE,ALIVE);

DATA APRNOVHT; SET ANOVHTS;
   PCSURV=DIV(NLIVE,ALIVE);
   IF PCSURV¬>0 THEN PCSURV=MISS(PCSURV);

PROC PRINT DATA=APRNOVHT; BY SITE; ID SPECIES POT CAGE;
   VAR NLIVE ALIVE PCSURV;

PROC ANOVA DATA=ANOVHTS; CLASSES SITE SPECIES; MEANS SITE|SPECIES;
MODEL SML LRG PCSURV DEAD GRAZED MISPLNTS TOTGRAZD = SITE|SPECIES;
  POOL 'SSP' SITE*SPECIES/SITE;
  TEST SITE BY 'SSP';
  TEST SPECIES BY 'SSP';
```

DATA SET ANOVHTS

CLASSES	VALUES
SITE	0 9
SPECIES	ARFR ARTR ATCA CELA CELE CEMO CEOV COME EPVI FAPA PUTR RIAU

```
PROC MEANS DATA=ANOVHTS;
  VAR SML LRG PCSURV DEAD GRAZED MISPLNTS TOTGRAZD;
  BY SITE SPECIES;
```

Table 1. Mean growing season growth and survival and fall utilization of 12 introduced browse species on two soil types by species and by soil type.

Species	Growth(cm)	Survival(%)	Utilization (cm)	Utilization(%)
Fringed Sagebrush	*[1]	100 g	2.0 ab	11 ab
Big Sagebrush	11.00 b[2]	45 d	6.0 bc	36 cd
Fourwing Saltbush	18.41 cd	93 g	21.5 f	65 e
Winterfat	8.25 b	66 f	+[3]	+
Curlleaf Mountain-Mahogany	-1.87 a	16 a	+	+
True Mountain-Mahogany	*	100 g	2.0 ab	4 ab
Jersey Tea	7.16 b	29 bc	16.0 e	100 f
Cliffrose	18.91 d	41 cd	9.8 cd	36 cd
Morman Tea	-0.42 a	60 ef	10.3 d	90 f
Apache-plume	28.42 e	60 ef	16.0 e	47 de
Bitterbrush	14.79 c	50 de	7.9 cd	25 bc
Golden Currant	-0.35 a	24 ab	00 a	15 a
LSD .05	3.84	11	4.03	21
Soil Type				
Grainola	11.84	61	7.8	28
Lucien	11.08	43	8.7	39
Probability Level	.66	01	.64	27

[1]Plants transplanted from southeastern Colorado on April 7, but initial average height not determined.

[2]Mean for species in the same column followed by a similar letter are not significantly different at the 0.05 level of probability.

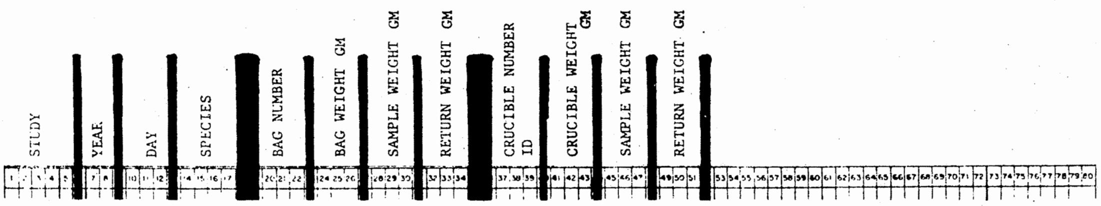
[3]Plants were either dead or too few to determine utilization.

APPENDIX L

IN VIVO AND PLANT CHEMICAL COMPOSITION

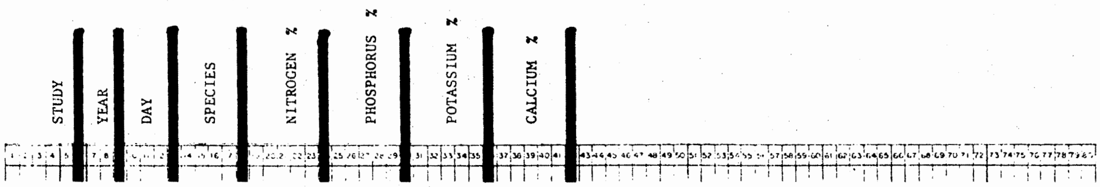
DATA SHEETS, INPUT, COMMENT, AND

COMPUTER PROGRAM STATEMENTS




```
DATA SINDM; INPUT
  STUDY $ 1-5 YR 7-8 DAY 10-12 SP $ 14-17 BAGNUM 20-22 BAGWT 24-26 2
   SAMPWTA 28-30 2 RETWTA 32-34 2 CRUCNUM 37-38 CRUCID $ 39 CRUCWT 41-43 2
   SAMPWTB 45-47 2 RETWTB 49-51 2;
   NETWTA = BAGWT + SAMPWTA;
   IF SP='NOSP' THEN NOSPCF=NETWTA/RETWTA;
   NOSPCFX=AVG(NOSPCF);

COMMENT
   STUDY SHRUB INVIVO DMD AND DRY MATTER DETERMINATIONS
   DAY AND YEAR  11/21/77
   SPECIES
     ARTR=ARTEMISIA TRIDENTATA ATCA=ATRIPLEX CANESCENS
     COME=COWANIA MEXICANA STANSBURIANA FAFA=FALLUGIA PARADOXA
     PUTR=PURSHIA TRIDENTATA  NOSP=NO SPECIES(CONTROL)
   BAG NUMBER IDENTIFICATION NUMBER ON EACH INVIVO BAG
   BAG WEIGHT THE DRY WEIGHT OF EACH INVIVO BAG
   SAMPLE WEIGHT THE WEIGHT OF FORAGE SAMPLE PUT IN INVIVO BAG
   RETURN WEIGHT DRY WEIGHT OF SAMPLE AND BAG AFTER INVIVO PROCESS
   CRUCIBLE NUMBER IDENTIFICATION AND CRUCIBLE NUMBER
   CRUCIBLE WEIGHT DRY WEIGHT OF CRUCIBLE
   SAMPLE WEIGHT THE WEIGHT OF SAMPLE PLACED IN CRUCIBLE FOR DM DETERMINATION
   RETURN WT THE DRY WEIGHT OF SAMPLE AND CRUCIBLE AFTER DM PROCESS;


PROC PRINT DATA=SINDM; ID DAY SP;
  VAR BAGWT SAMPWTA NETWTA RETWTA NOSPCF;


PROC MEANS NOPRINT OUT=SINDMX DATA=SINDM; BY SP;
  VAR BAGWT SAMPWTA NETWTA RETWTA NOSPCFX;


PROC PRINT DATA=SINDMX; BY DAY; ID SP;
  VAR BAGWT SAMPWTA NETWTA RETWTA NOSPCFX;


DATA SDMS; SET SINDMX; IF DAY > 1;
   MISMPL=(RETWTA* .846  )-BAGWT; 1/
   DMD=(SAMPWTA-MISMPL)/SAMPWTA;


PROC PRINT DATA=SDMS;   BY DAY; ID SP;
  VAR BAGWT SAMPWTA NETWTA RETWTA MISMPL DMD NOSPCFX;
```

1/ .846 = NOSPCFX




```
DATA PCHCM; INPUT
  STUDY $ 1-5 YR 7-8 DAY 10-12 SPECIES $ 14-17 NITROGEN 19-23 2
    PHOS 25-29 3 POTAS 31-35 2 CALCIUM 37-41 3;


COMMENT
    STUDY = PLANT CHEMICAL COMPOSITION
    DAY AND YEAR  3/15/78
    SPECIES
      PUTR = PURSHIA TRIDENTATA  ATCA = ATRIPLEX CANESCENS
      CEOV = CEANOTHUS OVATUS  ARTR = ARTEMISIA TRIDENTATA
      CELA = CERATOIDES LANATA COME = COWANIA MEXICANA EPVI = EPHEDRA VIRIDUS
      FAPA = FALLUGIA PARADOXA  RIAU = RIBES AUREUM
      CEMO = CERCOCARPUS MONTANUS  ARFR = ARTEMISIA FRIGIDA
    N = KJELDAHL NITROGEN IN FORAGE SAMPLE (%)
    P = PHOSPHORUS CONTENT OF FORAGE SAMPLE (%)
    K = POTASSIUM CONTENT OF FORAGE SAMPLE (%)
    CA = CALCIUM CONTENT OF FORAGE SAMPLE (%);


PROC PRINT DATA=PCHCM; ID DAY SPECIES;
  VAR NITROGEN PHOS POTAS CALCIUM;


PROC MEANS DATA=PCHCM;
  VAR NITROGEN PHOS POTAS CALCIUM;
  BY DAY SPECIES;


PROC MEANS NOPRINT OUT=PCHCMX DATA=PCHCM; BY SPECIES;
  VAR NITROGEN PHOS POTAS CALCIUM;


PROC PRINT DATA=PCHCMX; BY DAY; ID SPECIES;
  VAR NITROGEN PHOS POTAS CALCIUM;
```

VITA

Neal D. Stidham

Candidate for the Degree of

Master of Science

Thesis: GERMINATION, GROWTH, ESTABLISHMENT, UTILIZATION, AND CHEMICAL COMPOSITION OF INTRODUCED SHURBS ON NORTH CENTRAL OKLAHOMA RANGELAND

Major Field: Agronomy

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Personal Data: Born in Clinton, Oklahoma, May 18, 1952, the son of Mr. and Mrs. Walter C. Stidham. Married Charlotte Ann Shephard August 20, 1974.

Education: Graduate from Clinton High School, Clinton, Oklahoma, in May, 1970; received Bachelor of Science degree in Wildlife Ecology from Oklahoma State University in 1975; completed requirements for the Master of Science degree at Oklahoma State University in July, 1978.

Professional Experience: Three-Quarter Time Range Research Technician, Oklahoma State University, 1977 - present.

Professional Organization: Society for Range Management.